BIOLOGICAL ASSESSMENT

COLUMBIA RIVER CHANNEL IMPROVEMENTS PROJECT

December 28, 2001

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1 INTRODUCTION

The U.S. Army Corps of Engineers (Corps) has prepared this Columbia River Channel Improvements Project (the Project) Biological Assessment (BA) to evaluate potential effects on federally listed threatened and endangered salmonids that may be associated with proposed channel improvements. This section of the BA provides background information on the Project by summarizing the regulatory context for the reconsultation process and by introducing the major features of this assessment. The project is a multipurpose action consisting of navigation improvements and ecosystem restoration features. The Mouth of the Columbia River (MCR) Project (River Mile [RM] -3 to RM +3) is a separately authorized project and not covered in this BA.

1.1 Channel Improvements Project Background

1.1.1 History of Channel Improvements

The proposed deepening of the lower Columbia River navigation channel to 43 feet in depth has an extensive history and is part of the ongoing evolution of marine commerce within the Columbia River Basin. This section provides the background and context for the proposed action and for the analysis that has been performed to evaluate possible effects from that action.

Since the late 1800s, the Corps has been responsible for maintaining navigation safety on the Columbia River. During that time, the Corps has taken many actions to improve and maintain the navigation channel. The channel has been dredged periodically to make it deeper and wider, as well as annually for maintenance. To improve navigation and reduce maintenance dredging, the channel has also been realigned and hydraulic control structures, such as in-water fills, channel constrictions, and pile dikes, have been built. Pile dikes have been used to provide bank protection, channel stabilization, and channel constriction (with and without sand fill) and to concentrate flow. (Pile dikes are permeable groins extending into the river, and consist of two rows of untreated timber piling driven on 2 ½-foot centers alternately placed on each side of horizontal spreader piles. The pilings are driven to refusal, or to a specific penetration depending on location, and securely bolted to the spreader piles. Stone is placed along the pile dike and around the outer end for protection from scour.)

In 1878, Congress authorized the Columbia River navigation channel project and directed the Corps to establish and maintain a 20-foot minimum channel depth. Maintaining this depth required dredging in only a few shallow reaches of the river where the natural controlling depths were in the 12- to 15-foot range (Corps, 1999a). Pile dike construction in the lower Columbia River was initiated in 1885 at St. Helens Bar where natural depths of 15 feet were increased to 25 feet. Other early dikes were constructed at Martin Island Bar and Walker Island Bar in 1892-93.

In 1899, Congress increased the authorized navigation channel depth to 25 feet. The maintenance dredging associated with this increase was still limited to a few particularly shallow reaches where sporadic dredging was conducted as needed (Corps, 1999a).

In 1912, the navigation channel depth was increased to 30 feet. At that time, the navigation channel width was established at 300 feet. Increasing the channel depth to 30 feet resulted in the need for increased maintenance dredging to ensure that authorized navigation depths were safe, were available for shipping, and addressed shoaling associated with dredging (Corps, 1999a).

In 1930, Congress increased the authorized depth to 35 feet. The navigation channel width was also increased to 500 feet and was realigned in certain reaches. The channel deepening to 35 feet was completed in 1935. Most of the present-day dike system was built in the periods 1917-23 and 1933-39. From 1936 to 1957, Congress authorized additional channel alignment adjustments that added to the dredging requirements. During this period, dredging averaged 6.7 million cubic yards (mcy) per year. By 1958, the channel alignment had stabilized, but maintenance dredging was augmented to increase the advanced maintenance depth from 2 feet to 5 feet in areas of active shoaling. This "advance maintenance dredging" approach enhances navigational safety by maintaining the authorized channel depth (which is necessary to ensure adequate underkeel clearance) during periods of channel shoaling that occur between maintenance dredging events. Advance maintenance dredging in the navigation channel is ongoing.

The current 40-foot navigation channel was authorized in 1962; construction took place in stages between 1964 and 1976. The channel is 40 feet deep and 600 feet wide from RM 3.0 to RM 105.5, and 35 feet deep and 500 feet wide from RM 105.5 to 106.5 (from the Burlington Northern and Santa Fe Railway bridge to the Interstate 5 bridge). The 40-foot navigation channel generally follows the deepest part of the natural river channel. Most of the channel is naturally deeper than 40 feet; however, shoals tend to form in channel reaches where natural depth is less than 40 feet. Since 1976, maintenance dredging has averaged approximately 5.5 mcy per year (excluding emergency dredging related to the 1980 eruption of Mount St. Helens) (Corps, 1999a). Between 1957 and 1967, 35 new pile dikes were built. The existing dike system consists of 256 dikes, totaling 240,000 linear feet.

A period of riverbed adjustment has followed each navigation channel improvement. Each channel deepening may be viewed as a low-intensity disturbance that affects various reaches of the river. The riverbed slowly adjusts the side slopes adjacent to each new dredge cut. It typically takes several years for the side slopes to approach a dynamic equilibrium with the deepened channel (Corps, 1999a). Localized maintenance dredging has historically increased throughout the affected river reaches during these adjustment periods. The amount of dredging needed to maintain the navigation channel during these adjustment periods has depended partly on the magnitude of the disturbances to the pre-existing riverbed.

Because of the frequency and variation of channel improvements, there has not been a clear correlation between channel depth and maintenance dredging volumes. As noted above, the average annual maintenance dredging volumes for the 30-, 35-, and 40-foot channels were from 5.5 to 6.7 mcy per year (Corps, 1999a).

In December 1999, Congress authorized the deepening of the Columbia and Lower Willamette Rivers Federal Navigation Channel to 43 feet (Section 101(b)(13) of the Water Resource Development Act of 1999). The authorized plan would modify the existing federal navigation project for the Columbia and Willamette Rivers and provide for construction of ecosystem restoration features. Portions of the Lower Willamette River have been designated as a federal National Priorities List (NPL) site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). As discussed in Section 6.4, construction of the Willamette River features has been deferred pending study and selection of an appropriate remedy for cleanup under CERCLA. Following selection of the remedy, the Willamette River features will be re-evaluated and consulted on separately.

1.1.1.1 43-foot Channel Improvements Project

In the late 1980s, several lower Columbia River ports requested that the Corps consider additional deepening of the navigation channel. On August 3, 1989, the U.S. House of Representatives' Committee on Public Works and Transportation authorized the Corps to conduct a study of improvements for the navigation channel of the lower Columbia River. Specific guidance for conducting the feasibility study phase was provided in the Energy and Water Appropriation Act of Fiscal Year 1994, Public Law 103-126. The guidance limited the scope of the study to channel depths of no greater than 43 feet, as had been requested by the Sponsor Ports (Astoria,[1] Portland, and St. Helens in Oregon and Kalama, Longview, Vancouver, and Woodland in Washington). The first phase of this study was a reconnaissance study. The second phase, the feasibility study, began in 1994.

The Corps, with the cooperation of the lower Columbia River Ports completed the 5-year feasibility study, including an Environmental Impact Statement (EIS), in August 1999. Congress authorized construction of the project during its 1999 session, although additional funds must still be appropriated before the channel improvement work can begin. The recommended plan in the Final Environmental Impact Statement (FEIS) consists of the following:

- The existing 600-foot-wide, 40-foot-deep navigation channel would be deepened from -40 feet to -43 feet Columbia River Datum (CRD), from RM 3 to RM 106.5 on the Columbia River, including advanced maintenance dredging for overwidth and overdepth in the reaches where this practice is currently performed in the maintenance program.

- The existing 600-foot-wide, 40-foot-deep navigation project channel would be deepened from -40 feet to -43 feet CRD, from RM 0 to RM 11.6 on the Willamette River.[2]

- Three of the existing five turning basins on the Columbia River (located at RM 15, 73.5, and 101.5, respectively) would be deepened to -43 feet CRD.

- The three turning basins located at RM 4, 10, and 11.7 on the Willamette River would be deepened to -43 feet CRD.

- A total of 29 upland disposal sites (with a total land area of 1,681 acres), three beach nourishment sites, and one ocean disposal site would be required for the disposal of construction materials and subsequent channel maintenance dredged material. Fourteen of the upland disposal sites, totaling 1,025 acres, are currently in use, as are the three beach nourishment sites.

- Ecosystem restoration features include the use of a combined pump/gravity water supply for restoring wetland and riparian habitat at Shillapoo Lake. Tidegate retrofits with fish slides for salmonid passage would be installed at selected locations along the lower Columbia River. Connecting channels would be constructed at the upstream end of Walker-Lord and Hump-Fisher Islands to improve fish access to embayment rearing habitat for juvenile salmonids.

- Environmental mitigation features would be constructed on a total of 740 acres of land located at the Woodland Bottoms, Martin Island, and Webb mitigation sites.

Only one (deep water site) of the two authorized ocean disposal sites will be used for this Project. As discussed in detail in Section 8, additional ecosystem restoration features have been incorporated into the Project as a result of the informal consultation. These features would be constructed using several different means. The Lois Island Embayment and Miller-Pillar habitat restoration efforts would be constructed via placement of dredged material to attain target depths at each location. Miller-Pillar would also require construction of a pile dike field (five pile dikes) to hold material in place. The Bachelor Slough Restoration would entail deepening an existing side channel by dredging and disposal of material either upland or in or adjacent to the navigation channel. Upland disposal of Bachelor Slough sediments would allow for the development of riparian forest habitat with the Endangered Species Act (ESA)

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[1] Although originally part of the cooperating Columbia River Ports, the Port of Astoria is no longer a project sponsor.

[2] As discussed in Section 6, the Willamette River portion of the authorized improvements will be deferred.

Critical Habitat zone for Snake River salmonids. Purple loosestrife control would entail use of an integrated pest management approach, e.g., introduction of biological control agents, use of herbicides, and/or mechanical pulling of this exotic plant.

The interim restoration action at Tenasillahe Island would encompass improvements to existing tidegates and possibly placement of water control structures at inlets to interior sloughs to improve fish accessibility and water circulation through the sloughs. Over the long term, improvements at Tenasillahe Island could entail breaching of exterior dikes to return tidal circulation to 1,778 acres. The long-term action is contingent upon delisting of Columbia white-tailed deer and must be compatible with the purposes and goals of the refuge. The last restoration proposal pertains to the translocation of Columbia white-tailed deer to Cottonwood-Howard Island near Longview, Washington. No habitat restoration is required for this latter action.

This BA also addresses maintenance associated with the Project. Maintaining the 43-foot navigation channel requires annual ongoing maintenance to address shoaling action similar to the existing 40-foot project.

1.1.2 Project Need

The proposed Project is needed to maintain the existing trade base and restore ecosystem function. The identity and vitality of the Pacific Northwest is inextricably linked to the Columbia River Basin system for commerce and shipping.

1.1.2.1 Economic Importance of Channel Improvements

The Columbia River is a major gateway for waterborne cargo for the Pacific Northwest region and the United States. More than 35 million tons of cargo are shipped annually on approximately 2,000 ocean-going vessels via the ports of Kalama, Longview, and Vancouver in Washington, and Portland and St. Helens in Oregon. In 2000, cargo valued at $14 billion was shipped via lower Columbia River ports. In addition to the income generated by activities related to the navigation channel, the Corps has determined that channel deepening would result in national annual savings of $34.4 million in transportation costs (Corps, 1999a).

The lower Columbia River is the second largest grain-shipping waterway in the world, surpassed only by the Mississippi River. The Columbia River transportation corridor serves as a funnel for cargo moving from more than 40 states, which is then shipped from Columbia River ports (PIERS, 2001).

Since the last improvement to the Columbia River navigation channel, authorized in 1962, the volume of cargo carried by deep-draft vessels to and from Columbia River ports has tripled. During the same period, the average tonnage per vessel has also tripled, while the number of deep-draft vessels calling at Columbia River ports declined slightly.

Over the past 20 years, an increasing share of the Columbia River cargo tonnage has been carried on vessels that are Panamax class (the largest size vessels that can transit the Panama Canal) or larger. These larger vessels have design drafts that, after allowing for underkeel clearance requirements, exceed the depth allowed by the 40-foot channel; consequently, these ships must often come into the Columbia River ports "light-loaded" (i.e., only partially loaded). Currently, more than 70 percent of the vessels deployed in the transpacific container trade are constrained by the 40-foot channel depth. This amount would be reduced to 39 percent with a 43-foot channel.

1.1.2.2 Regional Benefits of Channel Improvements

The Columbia River navigation channel serves shippers located throughout the Pacific Northwest region. Regional growers, producers, and manufacturers use Columbia River ports to transport their goods to world markets. These shippers realize lower shipping costs by using Columbia River ports as opposed to more distant alternative ports. Marine shipping is an important industry in the lower Columbia River region. The Port of Portland estimates that approximately 40,000 jobs depend on Columbia River seaport activity. These jobs pay $46,000 per year per employee on average. The Port of Portland estimates Columbia River seaport activity generates $2 billion in business revenues and more than $200 million in state and local taxes each year. By lessening or removing the channel depth constraints for Columbia River seaport activity, the Project will continue to support this vital section of the regional economy.

1.1.2.3 Ecosystem Restoration

As discussed in detail in Section 2, the Columbia River system has been substantially altered over the last 100 years in a manner that has significantly degraded ecosystem functions. This Project responds to the well-demonstrated need for ecosystem restoration and, as discussed in Section 8, incorporates additional restoration actions.

1.2 Project Description

1.2.1 Project Actions

Details of the proposed actions to be undertaken are summarized in Section 3 of this BA. The selective dredging needed to deepen the 600-foot-wide Columbia River navigation channel to 43 feet from the current 40 feet would be done from RM 3.0 near the mouth of the Columbia River up to RM 106.5 near the eastern end of Hayden Island near Portland. Because significant reaches of the lower Columbia River and navigation channel are naturally deeper than 43 feet, only specific areas that are currently less than 43 feet deep will require dredging. These areas are identified in Figure 1-1 for the whole channel improvements project area. The shallower reaches that would be subject to deepening activities represent approximately 3.5 percent of the total river area between RM 3 and RM 106.5, or 54 percent of the existing navigation channel (Daly, pers. comm., 2001).

Figure 1-1: Navigation Channel Improvements Project Area

1.2.2 Study Area Considered in this Report

The National Marine Fisheries Service (NMFS), the U.S. Fish & Wildlife Service (USFWS), and the Corps have agreed to define the study area broadly for the Project BA. The action area is defined to extend beyond the actual location of proposed activities[3] to include areas that may potentially be directly or indirectly affected by the Project (50 CFR Section 402.02). The action area includes the following:

- A bank-to-bank run of the river from Bonneville Dam down to the river's mouth, which includes adjacent port terminals and berths and certain ecosystem restoration and mitigation sites, as well as from the river mouth extending 12 miles out into the Pacific Ocean in a fan shape.
- Upland disposal, ecosystem restoration, and mitigation sites.

All potential direct and indirect effects resulting from project activities in the action area are encompassed in this analysis, as are cumulative effects and effects from interrelated and interdependent activities. Although 11.6 miles of the lower Willamette River area were originally addressed in the FEIS and included in the Congressional authorization, the Willamette River is not included in this BA. It will be addressed in a separate BA after resolution of sediment cleanup issues associated with its designation as a federal NPL site under CERCLA.

For purposes of discussion, the action area has been divided into three general habitat or reach types. The first is riverine, which begins at Bonneville Dam and runs downstream to the start of the estuary at approximately RM 40. The second is estuarine and runs from RM 40 downstream to RM 3.[4] The third is the river mouth, which starts at a wide area at RM 3 and encompasses the outer boundary of the deep water site (approximately 12 miles beyond the project area), in a fan shape (Figure 1-2).

Within the three general reach types, the graphics in this document use the same reach segment breakdown as in the Corps' FEIS and Dredged Material Management Plan (DMMP). The reach numbering system used in the FEIS and DMMP runs from Reach 1 at RM 106.5 to Reach 7 at RM 3. However, the previous Corps' documents do not discuss the expanded Bonneville and river mouth reaches; consequently, reach numbers were not assigned to those areas. To avoid re-numbering the original reaches, the Bonneville reach has been designated Reach A, while the river mouth reach has been designated Reach B (Figure 1-2).

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[3] The location of the proposed project activities will be limited to dredging selected areas from RM 3 to RM 106.5, upland dredged material disposal in selected pre-approved upland and shoreline locations, and dredged material disposal in selected flowlane and ocean locations. (Details of these activities and locations are provided in Section 3.)

[4] Although the entire study area could be described as estuary because of tidal influence, only the portion influenced by increased salinity (RM 3 to RM 40) is referred to as estuary in this document.

Figure 1-2: Action Area

1.3 Environmental Regulatory Context for Channel Improvements

Informal consultation was reinitiated and this BA was prepared within a complex regulatory context. The following discussion is intended to explain the statutory basis for preparing the document and the broader regulatory context in which it is occurring.

1.3.1 Background on Endangered Species Act Consultation

Section 7 of the ESA of 1973 requires that federal agencies ensure that their actions are "not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical] habitat" [16 USC Section 1536 (a)(2)]. NMFS and USFWS share responsibility for the administration of the ESA, and federal agencies must consult with NMFS and USFWS if their activities could affect listed species or their habitat. In the Columbia, Willamette, and Snake Rivers, several fish species are listed as threatened and endangered under the ESA, with more awaiting listing determinations. USFWS has jurisdictional responsibility for the survival and recovery of listed fish species that spend the majority of their lives in freshwater. NMFS has jurisdictional responsibilities for listed fish species that spend the majority of their lives in saltwater.

A BA is prepared to "evaluate the potential effects of the action on listed and proposed species and designated and proposed critical habitat" (50 CFR Section 402.12). In preparing a BA, the federal agency uses the best available information to evaluate the potential effects of the action on listed species within the action area. Based on the effects that are identified through this process, the federal agency will determine whether formal consultation is necessary. When the federal agency completes its BA, it is submitted to NMFS and/or USFWS for review and formal consultation on whether the action will jeopardize the continued existence of the listed species or result in the destruction or adverse modification of their critical habitat. NMFS and/or USFWS document their findings and recommendations in a Biological Opinion (BO).

1.3.2 Reinitiation of ESA Consultation

The ESA consultation procedure for a federal action may be reinitiated if new information reveals potential effects to listed species not previously considered during an earlier consultation (50 CFR Section 402.16). This BA was prepared by the Corps in response to NMFS's request to reinitiate consultation on listed species potentially affected by the Project. This BA addresses 15 fish runs. It includes 13 listed fish runs, 1 fish run proposed for listing, and 1 candidate fish run[5] (Table 1-1). Thirteen of these 15 fish runs were evaluated during the previous consultation process.

[5] A fish run, as used in this BA, is a population segment of a salmonid species that forms an evolutionarily significant unit or distinct population segment as defined by the NMFS and USFWS.

Table 1-1: Fish Runs Addressed in This Biological Assessment

Responsible Agency	Runs	Listing Status
NMFS	Snake River fall chinook salmon (*Oncorhynchus tshawytscha)*[1]	Threatened
	Snake River spring/summer chinook salmon (*Oncorhynchus tshawytscha*)[1]	Threatened
	Snake River sockeye (*Oncorhynchus nerka*)[1]	Endangered
	Snake River steelhead (*Oncorhynchus mykiss*)[1]	Threatened
	Upper Willamette River chinook *(Oncorhynchus tshawytscha*)[1]	Threatened
	Upper Willamette River steelhead (*Oncorhynchus mykiss*)[1]	Threatened
	Upper Columbia River steelhead (*Oncorhynchus mykiss*)[1]	Endangered
	Lower Columbia River steelhead (*Oncorhynchus mykiss*)[1]	Threatened
	Lower Columbia River chinook salmon (*Oncorhynchus tshawytscha*)[1]	Threatened
	Upper Columbia River spring chinook salmon (*Oncorhynchus tshawytscha*)[1]	Endangered
	Columbia River chum salmon (*Oncorhynchus keta*)[1]	Threatened
	Middle Columbia River steelhead (*Oncorhynchus mykiss*)[1]	Threatened
USFWS	Bull trout (*Salvelinus confluentus*)	Threatened
	Coastal cutthroat (*Oncorhynchus clarki clarki*)[1]	Proposed Threatened
NMFS	Lower Columbia River/Southwest Washington coho[2] (*Oncorhynchus kisutch)*	Candidate

[1] Runs previously addressed in the earlier BA and supplements.

[2] On July 25, 1995, NMFS designated this coho evolutionarily significant unit (ESU) as a candidate for listing. Although not officially listed as threatened or endangered under the ESA, coho are included here because federal agencies have the responsibility to consider potential effects from the proposed Project on candidate species for planning purposes.

The ESA consultation process for the Project before reinitiation of consultation is described below.

1.3.3 Other Federal Regulatory Compliance

As suggested by the Council on Environmental Quality guidelines, this ESA consultation and associated documentation have been integrated into the ongoing National Environmental Policy Act (NEPA) compliance effort to streamline the process (40 CFR Section 1506.4). The Corps intends to supplement the NEPA document, completed in August 1999, to incorporate modifications to the proposed action described in this BA.

Future requirements before construction include Section 401 Clean Water Act (CWA) certification and Coastal Zone Management Act (CZMA) determination for both Oregon and Washington, and a Record of Decision under NEPA.

NMFS has recently defined essential fish habitat (EFH) for Pacific Coast salmonids within Amendment 14 to the Pacific Coast Salmon Plan, which was approved in September 2000 (NMFS, 2000). The important elements of salmon essential fish habitat (EFH) are 1) estuarine rearing, 2) early ocean rearing and 3) juvenile and adult migration. Important features of estuarine and marine habitat are 1) adequate water quality, 2) adequate temperature, 3) adequate prey species and forage food, and 4) adequate depth, cover, marine vegetation, and algae in estuarine and shoreline habitats. A separate EFH consultation is being conducted by the Corps and NMFS.

1.3.4 ESA Consultation History

In conjunction with preparation of the channel improvements feasibility study and the FEIS, the Corps initiated the earlier ESA consultation with NMFS in 1995 and with USFWS in 1997 (the Services) pursuant to 16 USC Section 1536(a). The Corps' consultations with the Services were conducted separately, and separate BAs were prepared for each of the two agencies. To provide the regulatory context for this BA, Figure 1-3 summarizes key events in the ESA consultation process from the Congressional authorization to study channel improvements in 1989 through the projected issuance of two Biological Opinions in 2002. The following sections briefly describe the previous consultation processes for each agency.

1.3.4.1 ESA Consultation with National Marine Fisheries Service

In 1995, the Corps initiated consultation with NMFS concerning potential effects on listed fish species in the proposed action area. The Corps completed a BA for NMFS review that assessed the potential effects of the Project on 12 of the listed species noted in Table 1-2 (Corps, 1999b). In addition, the FEIS for the Project (Corps, 1999a) incorporated by reference (Chapter 6, Section 6.7.2) the ESA determinations for marine mammals and sea turtles from the DMMP BA in their entirety as the two actions were considered identical relative to the listed species. For more detailed background information on these listed marine mammals and sea turtles, the reader should reference the DMMP BA.

During the course of the consultation, the Corps and NMFS engaged in significant dialogue regarding the project, including several workshops on salinity modeling and coordination of anticipated effects. The BA for fish species under NMFS jurisdiction was completed in April 1999. The BA determined that the proposed project "may affect but is not likely to jeopardize any of the listed stocks" (Corps, 1999b). From April to November 1999, NMFS and the Corps continued to consult regarding the potential effects stated in the BA, and the adequacy of the conservation measures to be included as "terms and conditions." In addition, on July 27, 1999, the Corps supplemented its initial BA to include Southwestern Washington/Columbia River coastal cutthroat trout (*Oncorhynchus clarki clarki*), which had recently been jointly proposed for listing as a threatened species by NMFS and USFWS.[6] The Corps determined that the Project "may affect but is not likely to jeopardize" cutthroat trout, as it had for the other fish species assessed in the original BA (Corps, 1999c).

On December 3, 1999, based on several months of additional consultation with NMFS, the Corps amended its original BA to include performance of additional studies and conservation measures (Corps, 1999d). The BA amendment also included a proposal for monitoring and for reporting on restoration actions, study results, and project updates.

On December 16, 1999, NMFS issued a BO for the proposed Project. The BO determined that, based on the conservation measures proposed, the Project would not jeopardize the continued existence of the listed species found in the action area.

[6] ESA jurisdictional responsibilities for the coastal cutthroat trout were transferred to USFWS on April 5, 1999. (See NMFS letter dated November 26, 1999, in Appendix A.)

Figure 1-3: Channel Improvements Project: ESA Consultation Timeline

On August 25, 2000, NMFS requested reinitiation of consultation and officially withdrew the December 16, 1999, "no-jeopardy" BO. NMFS advised the Corps that, if consultation were reinitiated, NMFS would expect to work with the Corps to accomplish the following goals:

> "1) Thoroughly assess the implications of any relevant new information; 2) reach agreement on the specific details of required studies and monitoring, and a schedule for conducting this work; 3) clarify expectations for the completion of restoration work; and 4) make any necessary refinements in the conservation measures, including terms and conditions, that are provided in the biological opinion to protect listed species and their designated critical habitat."

The letter concluded that it was NMFS's expectation that these tasks be performed within the reconsultation process prior to re-issuance of a BO for the Project (see Appendix A).

The August 25, 2000, letter identified a limited scope for reconsultation. These goals and the expectations for this BA have subsequently been modified during discussions among the Corps, NMFS, and USFWS. The agencies have agreed it is reasonable to treat the reconsultation as a new start and, accordingly, that the Corps should prepare a new BA. This called for re-evaluating project effects on the listed salmonid ecosystem. This BA presents all information necessary to accomplish the goals of reconsultation.

1.3.4.2 ESA Consultation with USFWS

The Corps also prepared a BA as part of the consultation with USFWS on listed terrestrial plants and wildlife within the action area. The consultation process with USFWS began in 1997 and included the terrestrial species listed in Table 1-2.

Table 1-2: Listed USFWS Plant and Wildlife Species (addressed in the 1997-99 Consultation)

Species	Status
Columbia white-tailed deer (*Odeocoileus virginianus leucurus*)	Endangered
Marbled murrelet (*Brachyramphus marmoratus*)	Threatened
Western snowy plover (*Charadrius alexandrinus nivosus*)	Threatened
Brown pelican (*Pelecanus occidentialis*)	Endangered
Oregon silverspot butterfly (*Speyeria zerene hippolyta*)	Threatened
Water howellia (*Howellia aquatilis*)	Threatened
Golden Indian paintbrush (*Castilleja levisecta*)	Threatened
Bradshaw's lomatium (*Lomatium bradshawii*)	Endangered
Nelson's checkermallow (*Sidalcea nelsoniana*)	Threatened
Bald eagle (*Haliaeetus leucocephalus*)	Threatened – Proposed Delisting
Aleutian Canada goose (*Branta canadensis leucopareia*)	Delisted – Currently Monitored
Peregrine falcon (*Falco peregrinus*)	Delisted – Currently Monitored

This consultation on terrestrial species was completed in December 1999 and was not reinitiated; consequently in this BA, these species are only addressed to assess the new ecosystem restoration and research features.

The Corps submitted the initial BA addressing plant and wildlife species to USFWS in early 1998. The BA considered potential impacts from a variety of activities in a variety of locations. Based on discussions with USFWS during the informal consultation process, it was determined that it would be necessary for USFWS to conduct formal consultation and prepare a BO to evaluate whether contaminated sediments would be affected by dredging and disposal operations and, if so, whether they would have an effect on listed bald eagles (see USFWS letter dated April 22, 1999, Appendix A).[7]

During the course of formal consultation, the Corps coordinated extensively with USFWS regarding conservation and mitigation measures that would be appropriate for implementation with the project. Based on the Corps' analysis and negotiated conservation and reasonable and prudent measures for bald eagles and Columbia white-tailed deer, the USFWS issued a BO on December 6, 1999, stating that the proposed project was not likely to jeopardize relevant listed species within its jurisdiction (USFWS, 1999). USFWS provided specific terms and conditions to minimize the Project's effects on bald eagles and Columbia white-tailed deer, which are still valid.

Subsequently, on December 7, 2000, USFWS informed the Corps of two additional listed species requiring consultation (see USFWS letter dated December 7, 2000, Appendix A). USFWS indicated that it had recently become aware of historical indications of bull trout presence within the Columbia River estuary. USFWS also noted that conferencing on the proposed coastal cutthroat trout should be reinitiated with USFWS because NMFS had withdrawn its BO that included coastal cutthroat trout, which was now regulated by USFWS. As discussed below, USFWS is participating in the reconsultation process to address potential impacts to bull trout and coastal cutthroat trout, which are addressed in this BA.

1.3.5 Reconsultation Process

Although the previous ESA consultations for this project addressed a number of terrestrial species, marine mammals, and aquatic species, this reconsultation process focuses primarily on the 15 fish runs listed in Section 1.3.2 and includes coastal coho. The goals of the reconsultation have been modified since NMFS initiated reconsultation with its August 25, 2000, letter. The goals of the reconsultation that the Services and the Corps have mutually developed are a re-evaluation of potential project impacts; an analysis of these potential effects within the framework of an ecosystem-based conceptual model; and development of compliance measures and monitoring conditions based on the effects analysis. In addition, the six Sponsor Ports[8] have assisted the Corps as a nonfederal representative for both NMFS and USFWS consultations (see Corps letters dated October 16, 2000; October 27, 2000; May 21, 2001; and July 11, 2001, Appendix A).

To facilitate the overall goals of reconsultation, the Corps, the Services, and the Sponsor Ports retained Sustainable Ecosystems Institute (SEI), a public-benefit, science mediation group, to help frame scientific questions raised in connection with the proposed Project. SEI assembled a panel of seven nationally prominent technical experts to provide an independent, scientific, peer-review process to evaluate the potential environmental issues surrounding improvement of the navigation channel. For further information regarding the panel, see Appendix A. The SEI Panel members included the following:

- Dr. Martin Cody, University of California, Los Angeles
- Dr. Steven Bartell, The Cadmus Group, Inc., Oak Ridge
- Dr. Donald Boesch, Center for Environmental Sciences, University of Maryland, Cambridge
- Dr. Lawrance Curtis, Oregon State University, Corvallis
- Dr. Thomas Dunne, University of California, Santa Barbara

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[7] Although the USFWS letter focused on peregrine falcons, the issue was equally applicable to bald eagles, for which formal consultation was ultimately also performed.
[8] The Sponsor Ports designated as nonfederal representative for the Project are Portland and St. Helens, Oregon, and Kalama, Longview, Vancouver, and Woodland, Washington.

- Dr. Charles Goldman, Tahoe Research Group Director, University of California, Davis
- Dr. Thomas Quinn, University of Washington, Seattle

During the SEI panel review process, additional analysis was completed and discussed at a series of five public workshops between March and August, 2001. These workshops addressed important physical and biological project issues, including:

- Historical and Existing Status of the Lower Columbia River Ecosystem
- Numerical Modeling of Hydraulic Parameters
- Salmonid Estuarine Ecology
- Sediments and Sediment Quality
- Monitoring and Adaptive Management

The Corps, the Services, Sponsor Ports, and other technical experts presented technical reports and technical status reviews at these SEI panel workshops. Summaries of the SEI public workshops, the technical presentations delivered at the workshops, and the panel's summary report of the findings are available on the SEI Columbia River project website, *http://www.sei.org/columbia/home.html*. In addition, since early spring 2001, the Corps, the Services, and the Sponsor Ports have engaged in regular reconsultation meetings to discuss and resolve technical issues associated with the proposed project and its potential effects and have conducted additional numerical modeling for the estuary. Models were run at both Oregon Health and Science University/Oregon Graduate Institute (OHSU/OGI) and the Corps' Waterways Experiment Station (WES).

1.3.6 Biological Assessment Organization

This document has been organized to present the essential features of a BA in a systematic framework outlining baseline conditions, the proposed action, and the effects of the proposed action on the baseline conditions. It also presents a discussion of the actions proposed to minimize any potential effects and for ecosystem restoration. Table 1-3 is a summary of the content of this BA.

Table 1-3: Columbia River Navigation Channel Improvements Project BA Section Outline

Section	Content
Executive Summary	
Section 1: Introduction	Background information about the project and its history to help clarify the intent and purpose of this document.
Section 2: Lower Columbia River Environmental Setting	Description of historical and current ecosystem conditions in the action area. Information in this section is organized according to the conceptual model presented in Section 5.
Section 3: Proposed Action	Description of the proposed types of activities necessary to complete the Project and the anticipated locations of those activities.
Section 4: Species and Habitat Information	Description of the way in which the species addressed in this document use the ecosystem described in Section 2.
Section 5: Current System Function	A conceptual model for understanding and evaluating how potential changes to the ecosystem will affect the listed species covered by this consultation.
Section 6: Effects Analysis	Evaluation of the potential effects from the activities described in Section 3 on the species and habitats identified in Section 4, and the Columbia River ecosystem described in Section 2, using the conceptual model described in Section 5.
Section 7: Actions Associated with Effects of Dredging and Disposal	Description of the compliance and monitoring actions that the Corps believes are necessary to ensure that any potential effects are minimized
Section 8: Ecosystem Restoration and Research Actions	Description of additional activities that the Corps will initiate to enhance conditions and assist with the restoration of the lower Columbia River ecosystem and their effects.
Section 9: An Ecosystem Approach to Project Implementation Using an Adaptive Management Process	Description of how actions proposed in Section 7 and additional activities proposed in Section 8 are linked to the conceptual ecosystem model in Section 5. The approach is outlined for implementing project activities and the Adaptive Management process.
Section 10: Determination of Effect	Effects determination for each of the listed aquatic species and, where relevant, terrestrial species as well as designated critical habitat.
Section 11: Abbreviations and Acronyms	List of abbreviations and acronyms
Section 12: Glossary	Glossary of terms
Section 13: References	List of references

2 LOWER COLUMBIA RIVER ENVIRONMENTAL SETTING

2.1 Section Organization

This section provides an overview of the environmental setting and conditions in the lower Columbia River that are important to listed salmonid populations. These environmental conditions collectively influence the growth and survival of the salmonid species rearing in and migrating through the lower Columbia River. The historical environmental conditions of the river, prior to nonindigenous human influence, were considerably different from existing environmental conditions. Because these differences are important in assessing the potential for natural variability and the significance of incremental changes within the river ecosystem, both the historical and existing conditions are presented and discussed separately in this section.

The lower Columbia River is a dynamic and complex system. In order to present a systematic framework for addressing this complexity, a conceptual model of the lower Columbia River ecosystem was developed and is used to describe and evaluate potential changes associated with the proposed Project. The conceptual model is described in Section 5 and in more technical detail in Appendix E. To provide consistency throughout the BA, the discussions of the historical and existing environmental conditions in this section are organized to follow the conceptual model. In addition, historical and current conditions are provided for each of the three reach types in the action area: the freshwater or riverine reach (from Bonneville Dam to RM 40), the estuary (from RM 3 to 40), and the river mouth (from RM 3 to the outer boundary of the deep water site, approximately 12 miles beyond the project area).

The basic habitat-forming processes—physical forces of the ocean and river—create the conditions that define habitats. The habitat types, in turn, provide an opportunity for the primary plant production that gives rise to complicated food webs. All of these pathways combine to influence the growth and survival and, ultimately, the production and ocean entry of juvenile salmonids moving through the lower Columbia River. These processes and pathways are developed in the conceptual model and outlined briefly in Table 2-1 and shown in Figure 2-1. Basic components, the indicators of the functioning of the system, are also listed and described in Table 2-1. The discussion of historical and existing conditions follows the table.

Table 2-1: Conceptual Model Pathways and Indicators for Juvenile Salmonid Production in the Lower Columbia River

Model Pathways	Pathway Description	Model Components (Indicators)	Indicator Description
Habitat-Forming Processes	Physical processes that define the living conditions and provide the requirements fish naturally need within the river system are included in the Habitat-Forming Processes Pathway.	Suspended Sediment	Sand, silt, and clay transported in the water column
		Bedload	Sand grains rolling along the surface of the riverbed
		Woody Debris	Downed trees, logs, root wads, limbs
		Turbidity	Quality of opacity in water, influenced by suspended solids and phytoplankton
		Salinity	Saltwater introduced into freshwater areas through tidal ocean process
		Accretion/ Erosion	Deposited/carved sediments
		Bathymetry	Topographic configuration of the riverbed

Model Pathways	Pathway Description	Model Components (Indicators)	Indicator Description
Habitat Types	This pathway describes definable areas that provide the living requirements for fish in the Lower Columbia River	Tidal Marsh and Swamp	Areas between mean lower low water (MLLW) and mean higher high water (MHHW) dominated by emergent vegetation (marsh) and low shrubs (swamp) in estuarine and riverine areas.
		Shallow Water and Flats	Areas between 6-foot bathymetric line (depth) and MLLW
		Water Column	Areas in the river where depth is greater than 6feet
Habitat Primary Productivity	This pathway describes the biological mass of plant materials that provides the fundamental nutritional base for animals in the river system.	Light	Sunlight necessary for plant growth
		Nutrients	Inorganic source materials necessary for plant growth
		Imported Phytoplankton Production	Material from single-celled plants produced upstream above the dams and carried into lower reaches of the river
		Resident Phytoplankton Production	Material from single-celled plants produced in the lower reaches of the river
		Benthic Algae Production	Material from simple plant species that inhabit the river bottom
		Tidal Marsh and Swamp Production	Material from complex wetland plants (hydrophytes) present in tidal marshes and swamps
Food Web	The Food Web pathway shows the aquatic organisms and related links in a food web that supports growth and survival of salmonids.	Deposit Feeders	Benthic organisms such as annelid worms that feed on sediments, specifically organic material and detritus
		Mobile Macroinvertebrates	Large epibenthic organisms such as sand shrimp, crayfish, and crabs that reside and feed on sediments at the bottom of the river
		Insects	Organisms such as aphids and flies that feed on vegetation in freshwater wetlands, tidal marshes, and swamps
		Suspension/Deposit Feeders	Benthic and epibenthic organisms such as bivalves and some amphipods that feed on or at the interface between sediment and the water column
		Suspension Feeders	Organisms that feed from the water column itself, including zooplankton
		Tidal Marsh Macrodetritus	Dead and decaying remains of tidal marsh and tidal swamp areas that are an important food source for benthic communities
		Resident Microdetritus	Dead and decaying remains of resident phytoplankton and benthic algae, an important food source for zooplankton

Model Pathways	Pathway Description	Model Components (Indicators)	Indicator Description
		Imported Microdetritus	Dead remains of phytoplankton from upstream that serve as a food source for suspension and deposit feeders
Growth	The Growth Pathway highlights the factors involved in producing both the amount of food and access by fish to productive feeding areas.	Habitat Complexity, Connectivity, and Conveyance	Configuration of habitat mosaics that allow for movement of salmonids between those habitats
		Velocity Field	Areas of similar flow velocity within the river
		Bathymetry and Turbidity	River bottom and water clarity conditions that influence the ability of salmonids to locate their prey
		Feeding Habitat Opportunity	Physical characteristics that affect access to locations that are important for fish feeding
		Refugia	Shallow water and other low energy habitat areas used for resting and cover
		Habitat-Specific Food Availability	Ability of complex habitats to provide feeding opportunities when fish are present
Survival	The Survival Pathway is a summary of key factors controlling or affecting growth and migration.	Contaminants	Compounds that are environ-mentally persistent and bioaccumulative in fish and invertebrates
		Disease	Pathogens (viruses, bacteria, and parasites) that pose survival risks for salmon
		Suspended Solids	Sand, silt, clay, and organics transported within the water column
		Stranding	Trapping of young salmonids in areas with no connectivity to water column habitat
		Temperature and Salinity Extremes	Temperature or salinity conditions that are problematic to salmonid survival
		Turbidity	Water clarity as it pertains to potential for juvenile salmonids to be seen by predators
		Predation	Potential for piscivorous mammals, birds, and fish to prey on salmonids
		Entrainment	Trapping of fish or invertebrates into hopper or pipeline dredges

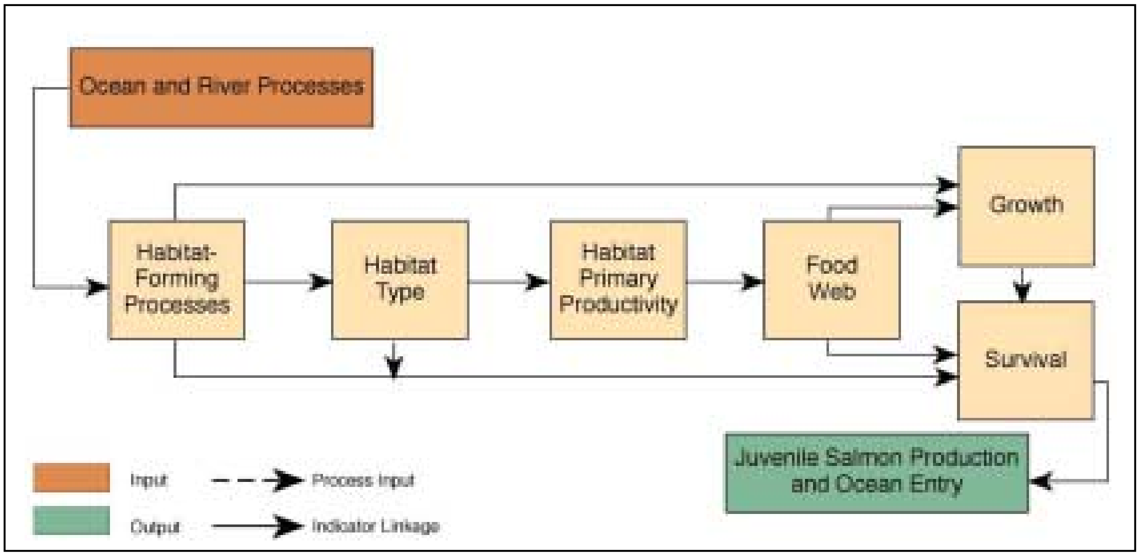

Figure 2-1: Integrated Model for Juvenile Salmonids in the Lower Columbia River

2.2 Historical Environmental Conditions

The Columbia River has been affected and shaped over eons by a variety of natural forces, including volcanic activity, floods, natural disasters, and climatological changes. These forces had and continue to have a significant influence on the biological factors (e.g., flow and temperature), habitat, inhabitants, and the whole riverine environment of the Columbia River. "Before human influence, the Columbia River estuary would have been a high-energy environment dominated by physical forces, with extensive sand-beds and highly variable river flows" (Independent Scientific Advisory Board [ISAB], 2000).

Over the past century, human activities have dampened the range of physical forces and resulted in extensive changes in the lower Columbia River and estuary system, particularly through changes to flow hydrographs, isolation of the floodplain, and development in wetland areas. Perhaps the greatest changes from human activity that influence the lower Columbia River system have been the reduction of the peak seasonal discharges and changes in the velocity and timing of flows as a result of dam controls. The riverine channel location has been very stable for centuries (Corps, 1999a). In the estuary, however, the main channel was not stable, shifting location from the north to the south side of the estuary in the 1800s.

The Columbia River estuary historically received annual spring freshet flows that were 75 to 100 percent higher on average than current freshet flows. Historical winter flows (from October through March) were also approximately 35 to 50 percent lower than current flows (Figure 2-2). The greater historical peak and variable flows encouraged greater sediment transport and more flooding of wetlands, contributing to the complex ecosystem of the estuary (ISAB, 2000).

Figure 2-2: River Flows at Bonneville Dam

The variable and unregulated river flow affected nearly every aspect of the historical ecosystem to some degree, including such diverse components as:

- Amount and distribution of woody debris
- Complexity and extent of tidal marsh vegetation
- Seasonal patterns of salinity and location of the estuarine turbidity maximum (ETM)
- Rates of sand and sediment transport
- Variations in temperature patterns
- Food web species and complexity
- Distribution and abundance of salmonid predators

"Floodwaters of the Columbia River historically inundated the margins and floodplains along the estuary, permitting juvenile salmon access to a wide expanse of low-velocity marshland and tidal channel habitats" (Bottom, et al., 2001). Flooding occurred frequently and was important to habitat diversity. Historical flooding also allowed more flow to side channels and bays and deposited more woody debris into the ecosystem.

Seasonal flooding increased the potential for salmonid feeding and resting areas in the estuary during the freshet season by creating significant tidal marsh vegetation and wetland areas. In general, the river banks were gently sloping, with riparian and wetland vegetation at the higher elevations of the river floodplain. It is estimated that the historical estuary had 75 percent more tidal swamps than the current estuary because tidal waters could reach floodplain areas that are now diked.

Prior to the river alterations initiated in the 19th century, five species of salmon joined in annual runs, estimated at 11 to 16 million, in a highly evolved, complex ecosystem that supported their complex life cycles. The ecosystem pathways sustaining the salmon and trout migrating through the lower Columbia River and a historical description of the most relevant components (i.e., indicators) of each of the pathways follows.

2.2.1 Historical Condition for Indicators Affecting Habitat-Forming Processes

Dynamic physical processes continually operate to shape and maintain the lower Columbia River ecosystem. The integration of these processes in time and space results in the conditions in which salmon and trout have evolved to meet their needs for growth and survival, and for entry to the ocean. This section is a discussion of the historical conditions of the relevant processes that form these salmon and trout habitats, including suspended sediment, bedload, woody debris, turbidity, salinity, accretion/erosion, and bathymetry.

2.2.1.1 Suspended Sediment

Suspended sediment is one of the sedimentation processes that affect both habitat formation and the direct survival of the fish as they move through the system. Suspended sediment is sand, silt, and clay transported within the water column. Particles are kept in suspension by the upward components of currents and turbulence. In relation to habitat-forming processes, deposition of suspended sediment can create shallow water areas that may ultimately support vegetation and become marsh or swamp areas. Historical (unregulated by dams) flows produced suspended sediment that contributed to the formation of a complex ecosystem within the estuary (ISAB, 2000).

Many of the ecosystem components within the project area are marked by historically high natural variability. Suspended sediment is one of these factors. Major geologic events, such as earthquakes, mudflows from Mount Hood and Mount St. Helens, and landslides, historically caused sporadic significant effects on suspended sediment transport.

Riverine Reach

The large peak flows associated with interior basin spring freshets and the western subbasin winter flood events transported large volumes of suspended sediment through the action area. From year to year, the size, duration, and timing of the spring freshets and winter floods varied widely, with proportionate variations in sediment yield. Historically (pre-dam) yearly streamflow maximums ranged from approximately 350,000 cubic feet per second (cfs) to 1,236,000 cfs for spring freshet flows (Bottom, et al., 2001). The Corps has estimated the recent historical (pre-dam) average annual suspended sediment load in the main river was approximately 12 mcy per year (Corps, 1999a). Most of the suspended sediment was silt and clay size material, with sand making up less than 30 percent of the load (Corps, 1999a).

Estuary

The 12-mcy-per-year average suspended sediment load in the river was delivered to the upper estuary just downstream of Puget Island. It has been estimated that about a third of the suspended silt and clay material that entered the estuary was deposited in the estuary (Hubbell and Glenn, 1973). It is likely that most of the suspended sand was also deposited in the estuary. Suspended sediment deposition in the estuary contributed to the creation of shallow water areas that ultimately supported vegetation and became marsh or swamp areas.

River Mouth

The historical suspended sediment discharge to the ocean was probably much less than the volumes being transported in the river because of the deposition that occurred in the estuary. Most transport to the ocean likely occurred during high freshet discharges or large winter floods.

2.2.1.2 Bedload

In the Columbia River, bedload is the movement of sand grains rolling and bouncing along the surface of the riverbed. In sandy riverbeds, such as the Columbia River, bedload transport shapes the bed into a series of sand waves. These waves move downstream as sediment erodes from the upstream face, deposits in the downstream trough, and is then buried by additional material eroded from the upstream face. This movement occurs in a layer only a few sand grains thick. Through this mechanism, all the individual grains in a sand wave are exposed to flow, eroded, transported, deposited, buried, and then eventually exposed again as the sand wave migrates downstream.

The rate of downstream migration of the sand waves in the Columbia River depends on the flow in the river. Observations have found bedload transport to be quite low at discharges below 300,000 cfs and to clearly rise at discharges over 400,000 cfs. Although bedload movement is primarily focused within the river's main channel, bedload may also play a role in the creation of shallow water and swamp habitat, which supports important life stages for salmonids. As noted in Section 2.2.1.1, the historical flood discharges were highly variable, with spring freshets typically exceeding 400,000 cfs for about 6 weeks and the 2-year peak discharge being 580,000 cfs (Corps, 1999a).

Riverine Reach

Historical (unregulated) average annual bedload transport in the main river channel has been estimated at 1.5 mcy per year (Corps, 1999a).

Estuary

Historic bedload transport rates in the estuary are unknown. It is likely that the rates were highly variable and followed trends similar to those of the present estuary as described in Section 2.3.1.1.

River Mouth

The historical bedload transport to the ocean is unknown. Ocean waves and tidal currents were major factors in bedload transport at the mouth.

2.2.1.3 Woody Debris

Large woody debris is an important habitat component for salmonids in the Columbia River system. Woody debris is particularly important in the upper reaches of tributaries and within smaller side channels of the mainstem. Woody debris creates structure along the channel edges that helps fish become oriented and provides food opportunities in the form of invertebrate fauna that feed on organic matter trapped in the debris. In shallow water areas, salmon can rest and find protection behind logs.

Riverine Reach

Prior to construction of the dams, it is likely that woody debris would have floated into and through the reach from upstream sources.

Estuary

In the historical estuary, adjacent riparian zones and flooding provided a continuous source of woody debris that enhanced sediment and organic matter storage and pool habitat. The presence of woody debris caused the estuary to be "characterized by spatially complex and diverse channel systems and highly productive salmon habitat" (National Research Council, 1995).

River Mouth

Not applicable.

2.2.1.4 Turbidity

Turbidity is a measure of light penetration through water and is a natural part of the habitat to which the young salmonids are adapted. Turbidity is a function of the amount of suspended sediment and plankton within the water column. The role of turbidity in biological processes is similar to those of suspended sediment (see Section 6.1.1). As with suspended sediment, turbidity levels increase with high river flows. Heavy wind and wave activity can also increase turbidity.

Turbidity plays an important role in several aspects of the action area. Turbidity is relevant to habitat-forming processes for listed salmonids because high turbidity levels can potentially limit the water depth at which plants can grow. These plants provide a variety of habitat values, including potential refugia and primary productivity.

Riverine Reach

Turbidity levels within the Columbia River historically followed the river's hydrograph closely, rising during spring freshets and western subbasin winter floods. The highest turbidity levels occurred during western subbasin winter floods.

Estuary

In addition to the turbidity entering the estuary from the main river, turbidity was generated by waves and current actions in the shallow flats and channels in the estuary. The location and extent of the historical ETM is unknown.

River Mouth

Although levels are not known, some turbidity historically occurred in the plume.

2.2.1.5 Salinity

Salinity intrusion is important as a habitat-forming process for three reasons. First, because plants and animals prefer particular ranges of salinity, the extent, duration, and concentration of the salinity intrusion can affect the formation of the swamp and marsh areas necessary for salmon as well as the availability of necessary food sources. Second, the transition zone between freshwater and saltwater is an area where juvenile salmonids spend time while adjusting to the saltwater environment. And third, the saltwater/freshwater interface creates a mixing zone referred to as the ETM (see Section 2.2.2.3, Water Column Habitat).

Riverine Reach

Salinity intrusion extends only to about RM 40, which divides the riverine area from the estuary. Therefore, salinity is not applicable in the river reach.

Estuary

The extent of salinity intrusion into the Columbia River estuary depends primarily on channel depth, strength of the tides, and river flows (Corps, 1999a; Columbia River Estuary Data Development Program [CREDDP], 1984). Although there are no data regarding the historical limits of salinity intrusion, salinity likely exhibited a significant seasonal range caused by the wide range of seasonal flows. It is possible that during high-volume spring freshets nearly the entire water column, to the river's mouth, was freshwater. During low flows, in late summer or fall, salinity intrusion may have extended as far upstream as RM 37.5 (CREDDP, 1984). The range of locations of the historical ETM is unknown.

River Mouth

Freshwater extrusion lowered salinity concentrations within the Columbia River plume, but the extent is unknown.

2.2.1.6 Accretion/Erosion

Accretion and erosion are the processes by which habitat types and landforms within the estuary and river are formed, shifted, and changed. Accretion typically occurs at a relatively slow rate as sediments settle from suspension in backwaters and slower-moving portions of the river channel. Erosion represents the counterbalancing process in which sediments are removed from an area.

On a geologic scale, the entire Columbia River valley downstream of Bonneville Dam is an accretion zone. The valley has been filled over the past 10,000 years as sea level rise has caused alluvial deposition. The estuary contains over 400 feet of alluvium.

Riverine Reach

Accretion and erosion occurred as sand moved around within the main river channel or entered the river from tributaries, primarily the Sandy and Willamette Rivers in Oregon and the Cowlitz River in Washington. These processes were most active during high discharge events. There was also accretion in the overbank areas during flood events. There was very little bank erosion, as the river channel's location has not changed much in 6,000 years (Corps, 1999a).

Estuary

Historically, the estuary has been an accretional zone. Spring freshets and winter floods carried significant sediment loads through the lower river, providing an opportunity for sediment deposition in the estuary. Over an extended period of time (thousands of years), this deposition led to the formation of the shallow water flats, marshes, and swamps found in and around the estuary in the late 1700s. It has been estimated that between 1858 and 1958 the average annual deposition rates in the estuary were somewhere in the range of 2 to 5 millimeters (mm) per year (CREDDP, 1984). The variability in estuarine accretion/erosion rates is illustrated by three sequential maps from the same location in Figure 2-3.

River Mouth

Historically, the river mouth has gone through cycles of accretion and erosion. Those cycles caused the entrance channel to move around and to shift between one and three main channels. The historical accretion/erosion rates are unknown. A single entrance channel was provided by the construction of the south and north jetties in 1885-1895 and 1913-1917, respectively. The construction of the jetties led to the accretion of Peacock Spit, a submerged ebb tidal delta, just outside the entrance.

Figure 2-3: Sediment Accretion and Erosion in Representative Portion of Columbia River Estuary, 1868-1982

2.2.1.7 Bathymetry

Bathymetry refers to the topographic configuration of the river, estuary, and ocean beds.

Riverine Reach

The riverbed between RM 106 and 146 was generally broad and shallow. Below RM 106, the historical bathymetry of this reach was variable, with long reaches of broad, shallow channels alternating with shorter, narrower, deeper reaches. The depth of the thalweg (the deepest portion of the channel) ranged from around 12 feet to over 50 feet (Corps, 1999a). The sandy riverbed had generally flat side-slopes and was covered with sand waves. The bathymetry shifted, especially during high discharges, as sand waves migrated downstream. There were only a few shallow side channels, such as those around Puget and Crimms Islands.

Estuary

The width of the river and its bathymetric variability increase as the river enters the estuary downstream of Puget Island. During the 1800s, the main river channel took various routes through the estuary, including courses along both the north and south sides of the estuary. In 1798, the main channel followed the north shore through much of the estuary and extensive sand flats existed in Baker, Grays, and Cathlamet Bays. By 1885, the main channel crossed from the north side near Harrington Point (RM 25) to the south shore at Tongue Point (RM 18) and followed the south shore out to the ocean. Also by 1885, the deep channel that in 1839 ran up into Baker Bay, just northeast of the entrance, had naturally filled in and Sand Island had been created. Smaller channels flowed around the many islands in Cathlamet Bay. There were also small channels through the shallow water flats in the central part of the estuary downstream of Harrington Point (RM 25). Those small channels shifted locations over time as sediment was eroded or deposited.

River Mouth

River mouth bathymetry historically shifted continuously in the river entrance and adjacent beaches. The entrance consisted of one or more channels that were generally less than 30 feet deep. A single entrance channel was provided by the construction of the south and north jetties in 1885-1895 and 1913-1917, respectively. By 1927, the entrance channel thalweg depth had increased to about 45 feet Mean Lower Low Water (MLLW). The construction of the jetties led to the formation of Peacock Spit, a submerged ebb tidal delta, just outside the entrance.

2.2.2 Historical Condition of Habitat Types

The processes discussed in Section 2.2.1 worked together to form a variety of habitats throughout the lower Columbia River. Certain habitat types are particularly important to salmon and trout in the Columbia River, including tidal marsh/swamp areas, shallow water/shoreline flats, and water column habitat (Figure 2-4). The following discussion of the historical availability of these habitat types is based primarily on surveys performed by CREDDP.

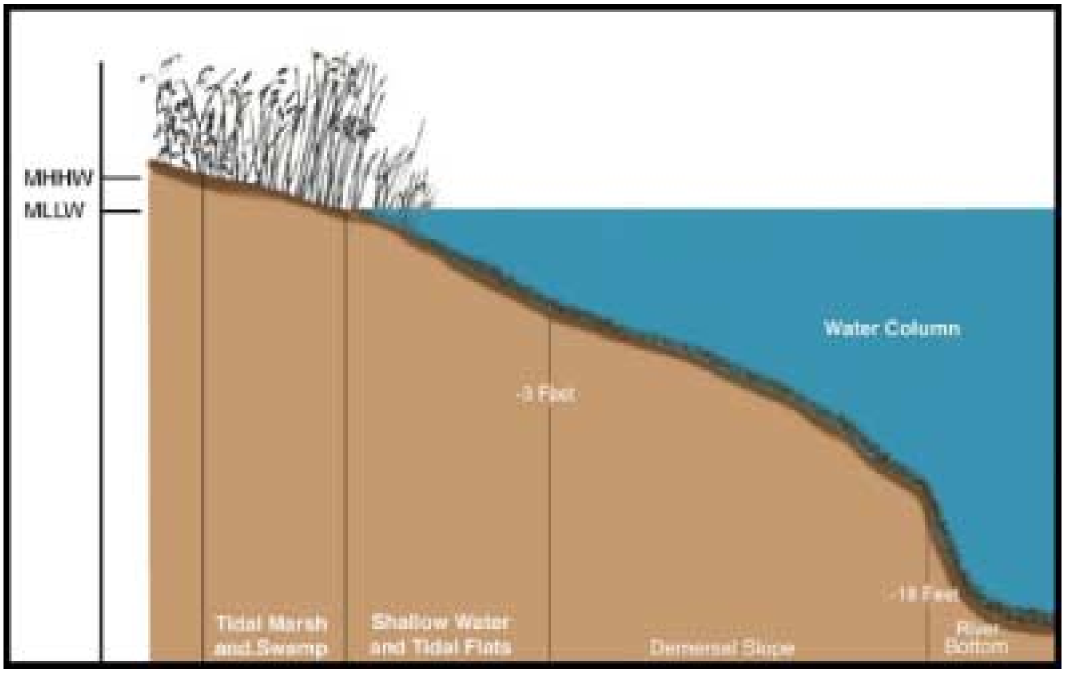

Figure 2-4: Major Habitat Types for Salmonids in the Lower Columbia River

<u>2.2.2.1 Tidal Marsh and Swamp Habitat</u>

Tidal marsh habitat refers to vegetated areas between MLLW and Mean Higher High Water (MHHW) that are dominated by emergent plants and low herbaceous shrubs. Tidal swamp habitat refers to vegetated areas dominated by wetland woody shrubs and trees that sometimes extend below the MHHW, but typically at elevations higher than those for tidal marshes (Thomas, 1983).

Tidal marsh and swamp habitats are the primary wetland and riparian communities adjacent to the river throughout the riverine and estuarine reaches of the action area. These habitats are designated as tidal habitats in this BA because they are subject to tidally induced inundation and include saltwater, brackish water, and freshwater components.

Riverine Reach

Historically, the lower Columbia River was characterized by large areas of tidal marsh and swamp habitat. See Estuary, below.

Estuary

The shoreline area along the lower Columbia River and estuary historically would have been subject to annual inundation from interior basin spring freshets. These annual high flows would have helped support the large areas of tidal marsh (approximately 16,000 acres) and tidal swamp (approximately 30,000 acres) habitat in freshwater and saltwater (Thomas, 1983). In addition, the large supply of suspended sediment deposition is likely to have continuously recharged marsh and swamp habitat and to have annually replenished nutrients and substrate.

River Mouth

Historically, the river mouth and shoreline of Baker Bay tended to be too exposed to wave energy to allow marsh and swamp habitat to develop (Thomas, 1983).

2.2.2.2 Shallow Water and Flats Habitat

Shallow water and flats habitat generally refers to the area between the 6-foot bathymetric line and the MHHW, approximately the outer edge of tidal marsh (Thomas, 1983). Shallow water areas shift continuously as new areas are formed through accretion and previously existing areas are eliminated by erosion.

Riverine Reach

Shallow water and tidal flat habitats are important for younger life stages of chinook and chum salmon, which may rear for up to several months in the shallow water habitats (Simenstad, et al., 1982). Thomas (1983) estimated that shallow water and flats habitat covered 40,640 acres in 1870.

Estuary

See Riverine Reach, above.

River Mouth

Historically, shallow water and tidal flat habitats were highly variable because shoaling, accretion, and erosion would create or eliminate habitat areas. An exception to the variability was the tendency for shallow water habitat areas to be maintained near the river mouth because wave energy prevented the formation of tidal marsh or swamp habitat (Thomas, 1983).

2.2.2.3 Water Column Habitat

Water column habitat encompasses those portions of the river where the depth is greater than 6 feet. Water column habitat is created and maintained by flow from the river's mainstem and tributaries. Water level and flows in the mouth and estuary are influenced by ocean tides. Tides also affect water level upstream of the estuary, but to a lesser extent. The water column, which is used primarily by stream-type juveniles and adult life stages of salmon, also serves an important function as an importer of phytoplankton and microdetritus from upstream areas.[9] In addition, the river transports sediments, most of which are fine sand and silt in suspension. Much of this sediment eventually settles out in the river, estuary, and mouth to form shoals and shallow flats.

[9] Detritus generally refers to dead and decaying plant materials. Organic material from dead phytoplankton and benthic plants is characterized as microdetritus because it is made up of the remains of single-celled plants. Organic material from dead tidal marsh and swamp plants is characterized as macrodetritus.

Riverine Reach

Water column habitat historically was present in the riverine reach. Natural migration of the main river channel resulted in shifting of the location of the river through time. Historical river flows varied, with spring freshets and fall-winter low-flow periods. The water column likely was dominated by phytoplankton and zooplankton produced in the river.

Estuary

As with the other habitat types, the lower river water column historically had a high degree of natural variability (Thomas, 1983). During the course of years, accretion and erosion within the system would create, change, eliminate, and recreate all of the various habitat types, including deep water habitats. For example, in the late 1800s, natural processes caused Sand Island to move from the middle of the river mouth into Baker Bay, resulting in the loss of 1,350 acres of deep water habitat. Historical documentation indicates that, at one time, major flow in the estuary was through the north channel (Thomas, 1983).

Historically, the estuary was the location where riverine- and estuarine-produced phytoplankton and zooplankton mixed. Saltwater and freshwater also mix in the estuary. In the Columbia River, as in most river-dominated estuaries, tidal processes and river flow resulted in a zone of increased turbidity called the ETM. The nonlinear circulation processes created by the outflow of the river and the inflow of tides promote the trapping and increased residence of organic and inorganic matter (Simenstad, et al., 1994). Freshwater plankton encountering the saline water will break down, further adding to the organic matter concentrated in the ETM.

River Mouth

Water column habitat historically was present in the river mouth. Processes occurring in the estuary have always influenced this portion of the system. The bottom contours are known to be constantly moving and shifting under influence from both the river and the ocean currents and waves. Consequently, the depth of the water column has varied through time.

2.2.3 Historical Condition for Indicators Affecting Habitat Primary Productivity

An important quality of the relevant salmonid habitat types discussed in Section 2.2.2 is their primary productivity, or ability to store energy in organic substances that are used as food sources in plants. This primary productivity is the foundation for the transfer of food energy, through series of organisms by feeding and being eaten, to the ultimate food sources important to salmonids. The primary producers are the plants that store energy in organic substances and provide basic food sources for food chains. The plant species that function as primary producers vary in type and abundance from habitat type to habitat type (Figure 2-5). For example, in shallow water habitats of the lower Columbia River, benthic algae are the primary food

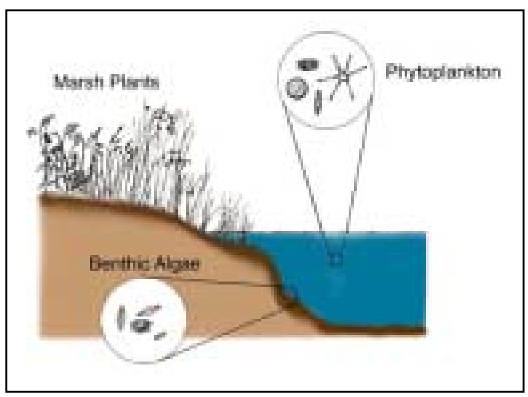

Figure 2-5: Major Primary Producers in the Lower Columbia River

source. In the water column habitat, the primary food source is phytoplankton (both resident and imported within the water column). For tidal marsh and swamp areas, the primary food source is complex vegetation, including emergent plants, shrubs, and trees.

Certain physical ecosystem components, such as light and nutrient availability, provide the energy source and material to drive primary productivity. The historical input of the necessary light and nutrients into the ecosystem and the resulting capacity of the relevant habitat to produce or provide the necessary food sources to salmon and trout are discussed below.

2.2.3.1 Light

Primary productivity and plant growth are driven by light energy. All food that is available for juvenile salmonids is made possible by the ability of plants to capture light, both at the water's edge in shallow water areas and in the water column itself. When turbidity is increased, light in the water column is reduced. This can result in less phytoplankton productivity as well as limit the depth at which submerged plants can be found.

Riverine Reach

Light limits phytoplankton productivity in the estuary section of the Columbia River (Sullivan, et al., 2001). Although it has not been studied extensively, it is reasonable to assume that this conclusion is also true for the riverine and river mouth sections. See also Estuary, below.

Estuary

Available information about historical conditions suggests that historical turbidity was greater in the water column than it is currently. The primary productivity within the shallow water and flats and the water column habitats would have decreased as turbidity increased; the depth at which photosynthesis occurred would also have decreased. Because light is currently a limiting factor in the lower Columbia River (CREDDP, 1984), it is presumed that it would have been a historical limiting factor as well. However, any decrease in primary productivity that resulted from increased turbidity was balanced by abundant organic macrodetritus from emergent plant species provided by the tidal marshes and swamps (Sherwood, et al., 1990).

Light penetration in the water column is affected by vertical mixing dynamics and turbidity resulting primarily from suspended sediments (Sullivan, et al., 2001). The current reduced flows have reduced suspended particulate matter concentrations during the spring freshet by a factor of two or more since pre-flow regulation. It is suspected that light penetration is greater now during most of the year than it was under historical conditions. This greater light penetration suggests that phytoplankton contributed less in the past to the suspended organic matter in all sections of the lower Columbia River.

River Mouth

Light limits phytoplankton productivity in the estuary section of the Columbia River (Sullivan, et al., 2001). Although this has not been studied extensively, it is reasonable to assume that this conclusion is also true for the riverine and river mouth sections. See also Estuary, above.

2.2.3.2 Nutrients

Inorganic nutrients such as nitrates and phosphates enter the system both from outside sources and as a byproduct of the breakdown of macrodetritus (Small and Morgan, 1994). Nutrients and light are required to support primary productivity in the system. If nutrients are in short supply, plant production is limited.

In the lower Columbia River, nutrient concentration varies seasonally. Inorganic nitrogen concentration is greatest in spring (March-May) and lowest in summer (June-September).

Riverine Reach

See Estuary, below.

Estuary

Historically, the breakdown of macrodetritus from the freshwater wetlands and tidal marshes and swamps provided a significant source of nutrient input to the estuary (Sullivan, et al., 2001). In addition, there are indications that resident phytoplankton production was more important than imported phytoplankton production in terms of nutrient transport to the lower Columbia River.

Light reduction caused by water column turbidity is believed to be more important in controlling phytoplankton production than is inorganic nutrient limitation (Sullivan, et al., 2001; Simenstad, pers. comm., 2001). The inverse correlation between phytoplankton production and river flow, and generally abundant nutrient levels suggest that diatom production within the action area is primarily limited by water retention time and light availability (Sullivan, et al., 2001).

River Mouth

See Estuary, above.

2.2.3.3 Imported Phytoplankton Production

Phytoplankton are microscopic, single-celled plants that float in the water column at a variety of depths (see Figure 2-5). Imported phytoplankton are phytoplankton that are produced upstream and carried into the lower Columbia River in the water column. Most of the phytoplankton within the lower Columbia are freshwater species imported from upstream locations (Small, et al., 1990). Dominant freshwater phytoplankton include *Asterionella formosa, Fragilaria crotensis, Melosira granulata*, and *Melosira italica* (Small, et al., 1990). These species mix with marine diatoms near the river mouth.

Some of the highest productivity rates for phytoplankton in the system occur in May and July, with sites nearest tributary rivers having the greatest rates. Reported productivity rates from these latter areas range from 750 to 1,000 milligrams of carbon per square centimeter per day. Rates in other areas range from 200 to 600 milligrams of carbon per square centimeter per day. Phytoplankton serve a vital role as the base of the food web on which zooplankton, benthic filter-feeding fauna, and epibenthic organisms feed.

Riverine Reach

See Estuary, below.

Estuary

While phytoplankton are the primary component of the existing Columbia estuary food web, historically it may have been less significant (Bottom and Jones, 1990). It is estimated that, with post-flow regulation, the annual input of imported phytoplankton input to the estuary (riverine and estuarine sections) has increased on the order of seven times (from 9,000 metric tons of carbon to 61,440 metric tons of carbon) compared with pre-flow regulation (Sherwood, et al., 1990). The phytoplankton species composition at any one point in the estuary was likely dynamic, shifting from marine-dominated during very low flows to freshwater-dominated during higher flows.

Imported phytoplankton had a role historically, but macrodetritus played a larger part in the food web. Marshes and swamps were historically more ubiquitous in the estuary. It is likely that the macrodetritus input from these tidal marshes and swamps was much more significant in the historical estuarine food web (Bottom and Jones, 1990).

River Mouth

See Estuary, above.

2.2.3.4 Resident Phytoplankton Production

Resident phytoplankton are those that are produced within the lower Columbia River. While phytoplankton are the primary component of the existing Columbia estuary food web, there is evidence that historically it was less significant. The most common taxa associated with the lower Columbia River are the salt-tolerant diatom species *Melosira granulata* and *Asterionella formosa* (Small, et al., 1990). As pointed out previously (Section 2.2.2.1), the marshes and swamps were historically more ubiquitous in the estuary, and macrodetritus likely played a much more significant role in the estuarine food web (Bottom and Jones, 1990).

Resident phytoplankton mix with nonresident phytoplankton in the estuary. Overall, phytoplankton production amounted to 37 percent of the total primary production in the lower Columbia system during studies conducted in the early 1980s (McIntire and Amspoker, 1984). The biomass of phytoplankton varies dramatically by season and location in the system as a result of variations in river flow, tides, and light (Small, et al., 1990). Values tend to be greatest in the upper portions of the estuary at sites near tributaries to the estuary (i.e., Lewis and Clark Rivers, Deep River).

Riverine Reach

The contribution of resident phytoplankton to the detrital food web, either before or after flow regulation, is not known. Estimates by Sherwood, et al. (1990), indicate that the amount may be similar in both pre- and post-flow regulation. The current relatively low levels of phytoplankton production within the estuary may be a result of the relatively quick flushing time associated with the lower river (CREDDP, 1984) compared with other estuarine systems. Because the freshwater phytoplankton are moving so quickly through the system, they do not have the opportunity to build up concentrated communities before they are exposed to lethal salinity levels and die. The current flushing time of the river is approximately 1 to 5 days, depending on flow and tidal conditions (CREDDP, 1984). Historical flushing times would likely have had a greater range as a result of the unregulated flow, but it is uncertain whether the greater range would have been large enough to significantly affect resident phytoplankton production.

Estuary

Production of resident phytoplankton in the Columbia River estuary is relatively low compared with other estuarine systems. There is no indication that resident phytoplankton production was ever a more significant part of primary production within the lower Columbia River than it is currently. However, because of the increased imported phytoplankton level, it is likely that the proportional, pre-flow regulation contribution of resident phytoplankton to total phytoplankton production was greater than it is currently.

Flow regulation has likely changed the spatial dynamics of resident phytoplankton production as well. The flow rates are not as seasonally variable with flow regulation, which potentially could allow phytoplankton populations to build up to greater concentrations than existed historically.

River Mouth

While marine phytoplankton predominate at the mouth of the estuary, the majority of phytoplankton within the estuary are, and likely were, merely an extension of the freshwater communities upstream (CREDDP, 1984).

2.2.3.5 Benthic Algae Production

Benthic (bottom-dwelling) algae production refers to the weight of new benthic algal organic material formed over a period of time, minus any losses during that period. Benthic algal productivity is the rate of production expressed as production divided by the period of time. Benthic primary producers can include flowering plants (*Zostera marina, Potamogeton richarsonii, Ceratophyllum demersum, Elodea canadensis*), macroalgae (*Ulva* spp., *Enteromorpha* spp.), and microalgae communities (diatoms, primarily of the genera *Navicula* and *Achnanthes*) that attach to the substrate (McIntire and Amspoker, 1984) (see Figure 2-5).

Historical data on benthic algae production are lacking. Historical rates are likely similar to current rates. Consequently, data collected in the early 1980s are used here to describe both historical and current conditions. Because of their distribution throughout the intertidal zones, diatoms are by far the most important benthic primary producer on the flats and in shallow water areas, and account for 7 percent of the primary production in the estuary. Annual benthic gross primary productivity rates in grams of carbon per square meter for various regions were 129 at Baker Bay, 94 at Youngs Bay, 34 at Grays Bay, 29 at Cathlamet Bay, and 37 in the upper estuary (McIntire and Amspoker, 1984). Diatoms are known to support production of benthic prey resources used by salmonids. The two most important factors for benthic algae production are light and sediment stability.

Riverine Reach

Benthic production within the riverine reach was likely focused in sheltered and shallow water areas. Because there were relatively fewer sheltered and shallow water areas, benthic production may have been of limited historical significance to the food web within the riverine reach. There are no published historical benthic algae production estimates from the riverine and river mouth as defined in this BA. The McIntire and Amspoker (1984) study sites extended well upstream into freshwater portions of the estuarine section. Benthic primary production rates from that study are summarized in the Estuary section below.

Estuary

Conditions in many parts of the estuary have never been conducive to production of benthic algae and flowering plants (CREDDP, 1984) because the Columbia River was historically relatively turbid, even during low-flow periods. However, sheltered areas and shallow water and flats habitat that harbored benthic algae may have been very productive and critically important to the estuarine food web. Within the estuary, most benthic primary production comes from microalgae and occurs within the shallow water and tidal flats habitat (Thomas, 1983).

Measurements of benthic algae production have been made in the estuarine portion of the study area by McIntire and Amspoker (1984, 1986). Benthic algae production was almost exclusively by benthic diatoms, although live phytoplankton cells were found in some benthic samples and may have contributed somewhat to benthic algae production. Annual benthic gross primary production averaged 72 grams of carbon per square meter. Areas with the lowest rates were the more exposed areas that contained coarse sediment grains, such as Clatsop Spit. Higher rates were recorded in more protected areas with finer grained sediments, such as inside Youngs and Baker Bays. Benthic macroalgae such as *Enteromorpha*, which are common in other Pacific Northwest estuaries, are rare in the lower Columbia River.

Total production on the tidal flats was estimated to be 2,837 metric tons of carbon per year (McIntire and Amspoker, 1986). Benthic algae associated with the lower edge of the tidal marsh accounted for an additional 2,085 metric tons of carbon annually. Of the 30,000 metric tons of carbon produced annually by phytoplankton, marshes, and benthic algae in the estuary, 7 percent (2,100 metric tons) was attributed to benthic microalgae, 37 percent (11,100 metric tons) to marsh macrophytes, and 56 percent (16,800 metric tons) to phytoplankton (Small, et al., 1990).

River Mouth

See Estuary, above.

2.2.3.6 Tidal Marsh and Swamp Production

Tidal marsh and swamp production refers to the weight (i.e., biomass) of new marsh and swamp plant organic material formed over a period of time, minus any losses during that period. Tidal marsh and swamp productivity is the rate of production expressed as production divided by the period of time. Tidal marsh and swamp production results in vegetation necessary to support insect life and, ultimately, to input macrodetritus into the system. The primary production from tidal marshes and swamps forms the basis for the macrodetrital food web that supports juvenile salmonids. Small fish forage at the edges of marsh channels for insects and benthic crustacea. The predominant tidal marsh and swamp habitats within the lower river historically would have produced macrodetritus within the system and also supported insect production (Thomas, 1983).

Riverine Reach

The river in the riverine portion of the action area historically was connected to floodplain areas, which would frequently develop tidal marsh and swamp characteristics. Seasonal inundation of these floodplain areas would promote plant growth that would support insects. In addition, inundation of floodplain areas during high spring freshet flows and large winter flood events would transport macrodetritus from the vegetated areas into the system. Total emergent plant production in the riverine and estuarine portions of the system pre-1870 was 62,629 metric tons of carbon per year (Sherwood, et al., 1990).

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

2.2.4 Historical Condition for Indicators Affecting Food Web

The historical abundance of salmonid stocks was in part related to the complex food webs that sustained juvenile salmonids migrating to the ocean. Within each habitat type, the chains of organisms feeding and being eaten form interconnected patterns or webs that ultimately provide prey for salmonids moving through the river ecosystem.

The trophic components of the salmonid food web discussed in this section are illustrated in Figure 2-6. These include the following categories:

- Deposit feeders
- Mobile macroinvertebrates
- Insects
- Suspension/deposit feeders
- Suspension feeders

2.2.4.1 Deposit Feeders

Deposit feeders are benthic animals that feed by ingesting material on the immediate surface of sediments or the sediments themselves, thereby obtaining organic matter and detritus. The primary known deposit feeders in the lower Columbia River are annelids (segmented worms). Both marine (polychaetes) and freshwater (oligochaetes) varieties are found within the action area. Annelids are important to the system because they provide a primary link between detritus and the mobile macroinvertebrates that are a food source for some life stages of salmon and trout (CREDDP, 1984). In addition, deposit feeders include some gammarid amphipods and harpacticoid copepods. These animals are often on or very near the surface.

Riverine Reach

See Estuary, below.

Estuary

Deposit feeders historically played a large role in the riverine and estuarine food web for salmonids. The abundance of tidal marshes and swamps and freshwater wetlands provided large amounts of macrodetritus for the deposit feeders. In particular, the food web leading through the deposit feeders from marsh macrodetritus was very important historically for juvenile salmonids (Weitkamp, 1994; Bottom, et al., 2001).

River Mouth

See Estuary, above.

2.2.4.2 Mobile Macroinvertebrates

Mobile macroinvertebrates are large epibenthic organisms that reside on the bottom of the river. Examples of macroinvertebrates in the lower Columbia River include shrimp (*Crangon franciscorum*), mysids (e.g., *Neomysis mercedis*), and Dungeness crab (*Cancer magister*) (CREDDP, 1984). These species make up most of the standing crop of mobile macroinvertebrates in the estuary. *Neomysis* and Dungeness crab are primarily brackish water organisms that occur in the lower estuary and occasionally in the central estuary when river flows are low and salinity extends farther upriver. *Neomysis* has been found in shallow areas upriver as far as RM 43.2 (McCabe and Hinton, 1996). *Crangon* account for most of the density of mobile macroinvertebrates in the central and upper estuary. Density is typically less than one animal per cubic meter. They occur predominantly in the shallow areas over the tidal flats, but can be found in the channel areas during low river flows, possibly because during high flow the velocity is too great for them to be in the channel areas.

Figure 2-6: Salmonid Food Web for the Lower Columbia River

Macroinvertebrates feed on epibenthic zooplankton (e.g., copepods), benthic infauna (e.g., *Corophium* and various polychaetes), and detritus (CREDDP, 1984).[10] Mobile macroinvertebrates, particularly mysids, are an important food source for juvenile salmonids (Simenstad and Cordell, 2000; Miller and Simenstad, 1997). Planktonic larvae forms, as well as other small benthic forms of this group, can be important in the diet of salmonids (Meyer, et al., 1980; Healey, 1991; Bottom and Jones, 1990).

Riverine Reach

See Estuary, below.

Estuary

As with other benthic and epibenthic food sources within the estuary, there was apparently ample habitat available for macroinvertebrates historically. It is likely that the various epibenthic salmon food sources were a larger part of the historical food web than they are currently (Sherwood, et al., 1990).

River Mouth

See Estuary, above.

2.2.4.3 Insects

Many insect species feed directly on the vegetation in freshwater wetlands and tidal marshes and swamps; consequently, they are directly dependent on marsh production and detritus. Emergent insects provide an important food source for juvenile salmonids in the estuary (Simenstad and Cordell, 2000; Miller and Simenstad, 1997). Some of the insects known to be of importance to salmonids include aphids, emergent chironomids, and other dipteran flies (Simenstad and Cordell, 2000; Miller and Simenstad, 1997). Weitkamp (1994) identified insects as an important food source for salmonids in the lower Columbia River.

Riverine Reach

See Estuary, below.

Estuary

Little is known of the historical abundance of insects within the riverine reach or estuary, but it is known that their primary habitats (freshwater wetlands and tidal marshes and swamps) were prevalent. Present-day marshes and swamps cover only 35 percent of the area covered prior to 1870 (Thomas, 1983).

River Mouth

See Estuary, above.

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[10] Epibenthic organisms occupy the area from the sediment surface to 1 meter above the sediment surface within the water column. Benthic fauna live primarily on top of or within the first layer of sediment on the river bottom. Benthic infauna refers specifically to those organisms that live within, rather than on top of, the river bottom.

2.2.4.4 Suspension/Deposit Feeders

Suspension/deposit feeders are benthic and epibenthic organisms that feed on or at the interface between the sediment and the water column. Suspension/deposit feeding typically involves some mechanism for sifting the upper level of sediment to obtain the associated organic materials. For example, *Corophium*, which are benthic infauna, construct a tube in the sediment from which they will occasionally make a foray to scoop in plant material and detritus from the surface (CREDDP, 1984). Examples of suspension/deposit feeders include some species of mysids, some species of bivalves (e.g., *Macoma balthica* and *Corbicula manilensis*), and some species of amphipoda (*e.g.*, *Corophium salmonis*, *Corophium brevis*, and *Corophium spinicorne*).

Suspension/deposit feeders are important to adult salmonids because of their role in the production of prey. *Eurytemora* and *Scottolana* are known to be important prey for planktivorous fish (e.g., Pacific herring, Pacific sand lance), which are preyed on by all adult salmonid species.

Riverine Reach

See Estuary, below.

Estuary

The benthic and epibenthic chain within the food web historically provided by suspension/deposit feeders was a prominent feature of the lower Columbia River ecosystem (Sherwood, et al., 1990). This aspect of the food web provided important support to juvenile salmonids.

River Mouth

See Estuary, above.

2.2.4.5 Suspension Feeders

Suspension feeders are organisms that feed from the water column itself. For zooplankton and benthic/epibenthic organisms, this is accomplished primarily through “filter feeding” (extracting organic matter from the water column by pumping or siphoning the water through their system). Examples of some of the significant suspension feeding organisms in the lower Columbia River include several species of copepod and freshwater cladocerans (e.g., *Bosmina* and *Daphnia* spp.).

Riverine Reach

See Estuary, below.

Estuary

Suspension feeders tend to support a water-column-based food web that favors such species as anchovy, herring, and longfin smelt, which are frequently consumed by older salmonids on their way out of the estuary (Bottom and Jones, 1990). Historically, suspension feeders most likely played an important role within the estuary and riverine sections, but may have been less abundant than now relative to suspension/deposit feeders and insects (Sherwood, et al., 1990).

River Mouth

See Estuary, above.

2.2.4.6 Tidal Marsh Macrodetritus

Tidal marsh macrodetritus is the dead and decaying plant remains from both the tidal marsh and the tidal swamp areas. The macrodetritus associated with the relatively large plant material growing in the tidal marshes and swamps provides an important food source for the benthic communities adjacent to the tidal marsh and swamp areas. In turn, these benthic communities provide an important food source to juvenile salmonids.

Riverine Reach

See Estuary, below.

Estuary

The lower Columbia River historically had a large supply of macrodetritus from the abundant tidal marshes and swamps located in the estuary (Thomas, 1983).

River Mouth

See Estuary, above.

2.2.4.7 Resident Microdetritus

Resident microdetritus is the dead and decaying remains of resident phytoplankton and benthic algae. Resident microdetritus is a food source for zooplankton (small, often microscopic animals floating in the water column) and benthic and epibenthic suspension and suspension/deposit feeders.

Riverine Reach

Resident microdetritus was present historically in the riverine section of the lower Columbia River. It likely was supported primarily by resident phytoplankton production and, to a much lesser extent, by benthic microalgal production occurring in shallow flats and channels.

Estuary

As stated in Section 2.2.3.4, there is a relatively low level of phytoplankton production within the estuary, which may result from the relatively quick flushing time associated with the lower river (CREDDP, 1984). If the resident phytoplankton production were also relatively low historically, which seems likely, then the planktonic source for resident microdetritus would have been limited. Conversely, there historically would have been more side channels, oxbows, and marshes to support phytoplankton growth.

The same would not be true of benthic algae, which is the other source for resident microdetritus, because benthic algae tend to flourish primarily in sheltered locations that are not subject to strong flows (CREDDP, 1984). Accordingly, benthic sources of microdetritus, which tend to support benthic and epibenthic feeders, would not have been affected by historical estuary flushing. However, benthic algae account for a relatively small proportion of microdetritus within the estuary.

River Mouth

See Estuary, above.

2.2.4.8 Imported Microdetritus

Imported microdetritus is mostly derived from algal production upriver, including that produced above dams, and is important for suspension feeders and suspension/deposit feeders.

Riverine Reach

See Estuary, below.

Estuary

Imported microdetritus in the estuary is composed primarily of the dead phytoplankton floating in the water column from upstream. Imported microdetritus functions within the food web similar to resident microdetritus. There is no reason to believe that before the creation of the upstream reservoirs the production rates varied greatly between resident and imported microdetritus.[11]

River Mouth

See Estuary, above.

2.2.5 Historical Condition for Indicators Affecting Growth

Attaining adequate growth is vital to the survival and migration of juvenile salmonids. The primary factors that ensure adequate growth opportunities are sufficient productive feeding areas. The ecosystem components that are relevant to ensuring that adequate growth opportunities exist include:

- Habitat complexity/connectivity/conveyance
- Velocity field
- Bathymetry and turbidity
- Feeding habitat opportunity
- Refugia
- Habitat-specific food availability

This section is a discussion of the historical condition within the lower Columbia River for these important growth factors.

2.2.5.1 Habitat Complexity, Connectivity, Conveyance

Aquatic habitats function to support listed salmonids and coho in the Columbia River through their complexity, geographic connections, and conveyance of energy and nutrients. The complexity of the lower Columbia River habitat types supports a variety of salmonid life history types and stages as the young salmonids grow during their downstream migrations. Connectivity refers to the configuration of habitat mosaics in time and space in a manner that allows for movement of salmonids between habitats. Conveyance describes the transport of organics and inorganics between habitats.

Riverine Reach

Appropriate habitats need to be available when salmonids require them for feeding, resting, and cover as they move up and down the river system. The lower Columbia River historically had a rich variety of

[11] Reservoirs on the Columbia River have caused significant increases in phytoplankton production within the river above Bonneville Dam (Sherwood, et al., 1990).

habitats in a mosaic that provided the complexity necessary for salmonids (Thomas, 1983). Permanent physical and topographical barriers among habitats or conditions that impeded habitat-forming processes were minor, and good connectivity among these habitats was likely, particularly during high-flow events.

Estuary

Juvenile salmonids moving downriver and through the estuary tend to use shallow water and tidal flats habitat. However, as water levels rise or fall, they will move into the tidal marsh areas or remain at the edges of deeper pools, respectively. The estuary historically contained large areas of tidal marsh as well as access to inundated floodplain.

River Mouth

See Estuary, above.

2.2.5.2 Velocity Field

Velocity field refers to speed and direction of flow velocity within the river. The relevant issue is whether adequate slower-moving or still shallow areas are available to salmonids while they are in the lower Columbia River. These areas are important to salmonid growth because juveniles are small and have relatively weak swimming capabilities; consequently, feeding is most effective in areas where current velocities are low.

Riverine Reach

See Estuary, below.

Estuary

The floodwaters of the Columbia River historically inundated the margins and the unimpeded floodplains along the river, providing access to marshland and tidal channel habitats with low-velocity fields (Bottom, et al., 2001). These tidal marshes and side channels were present in great abundance historically (Thomas, 1983).

River Mouth

See Estuary, above.

2.2.5.3 Bathymetry and Turbidity

In the context of growth opportunity, bathymetry and turbidity refer to the conditions that influence the ability of salmonids to locate their prey. Because salmonids are primarily visual predators, turbid waters may limit their ability to see prey, while uneven bathymetry may hide the prey from their sight.

Riverine Reach

See Estuary, below.

Estuary

Historically, the lower Columbia River had a highly variable bathymetry. In addition, the lower river was subject to high levels of turbidity, particularly during spring freshets and winter floods. These conditions may have limited the ability of salmonids to feed efficiently within the water column habitats; however, good connectivity to tidal marsh and floodplain areas mitigated the feeding conditions.

River Mouth

See Estuary, above.

2.2.5.4 Feeding Habitat Opportunity

The concept of habitat opportunity is discussed in *Salmon at River's End* (Bottom, et al., 2001). Habitat opportunity refers to those physical characteristics that affect access to geographical locations that are important to particular fish needs. "Feeding habitat opportunity" refers specifically to the ecosystem's ability to provide access to important feeding habitats. The characteristics that affect access to feeding habitats typically vary over short periods of time, often less than a day. They include water level elevation, water current speed (velocity), temperature, and salinity (see Sections 6.1.5, Salinity; 6.1.7, Bathymetry; and 6.1.26, Velocity Field). Habitat characteristics naturally vary daily with changes produced by tides, seasonally by predominant weather conditions, and over long periods with changes produced by humans such as dams, dredging, diking, and filling.

Riverine Reach

The lower Columbia River historically had significant tidal marsh and swamp areas as well as frequent flooding from spring freshets and flooding that provided access to such areas. These tidal marshes not only provided access to insects and benthic food sources, they also provided areas of low-velocity flow.

Estuary

See Riverine Reach, above.

River Mouth

Not applicable.

2.2.5.5 Refugia

Refugia refers to shallow water and other low-energy habitat areas temporarily used by salmonids for resting and cover. Lack of refugia can impede the growth of salmonids. Juvenile salmonids (particularly ocean-type, which are not strong swimmers) would expend considerable energy fighting currents without access to safe resting areas. Refugia are important to growth because the expenditure of calories to counter tides and river currents increases the amount of food that must be consumed. In addition, if refugia are not available, it is less likely that these calories will be available to salmonids for consumption because refugia also provide habitat for prey.

Riverine Reach

During times of historical high flows, when refugia from flow velocities would have been particularly important, the lower Columbia River had significant tidal marsh and floodplain areas accessible to salmonids.

Estuary

Prior to construction of the diking throughout the lower river, high flows would have extended the margins of the estuary outward, which would have increased the shallow water areas available for refuge significantly (Bottom, et al., 2001). A study conducted in 1916, which predates much of the diking, found that subyearlings collected for the study were able to remain in the estuary throughout the peak of an extremely high spring freshet (Rich, 1920).

River Mouth

Not applicable.

2.2.5.6 Habitat-Specific Food Availability

Habitat-specific food availability refers to the capability of habitat areas to provide feeding opportunities when and where they are needed by salmonids. Fish must be able to access the necessary complex habitats, but in addition these areas must support a food web that provides prey species when salmonids are feeding there. The food web within the action area is based in large part on detritus. As described in Section 2.2.3, detritus sources may include emergent plants from tidal marshes, benthic algae, resident phytoplankton, and imported phytoplankton from upstream sources.

Riverine Reach

See Estuary, below.

Estuary

The type of food web that develops within an ecosystem depends on the balance of the primary productivity sources within the system. The lower Columbia River historically had significant sources of macrodetritus and good opportunities for benthic suspension/deposit feeders (Thomas, 1983). Accordingly, it is likely that it had a balanced food web with both pelagic and benthic components.

River Mouth

See Estuary, above.

2.2.6 Historical Condition for Indicators Affecting Survival

A number of ecosystem factors influence the survival of salmonids within the lower Columbia River ecosystem. These factors include both physical and biological components that affect salmonids ability to rear and migrate through the system. Primary physical factors may include temperature and salinity extremes, stranding, and entrainment. Biological factors may include disease, predation, and competition. This section is a discussion of the historical conditions associated with the various relevant factors.

2.2.6.1 Contaminants

Contaminant levels in the Columbia River historically had some level of contamination that peaked after the turn of the century as a result of increased industrialization. State and federal laws governing the discharge of effluent into the river have resulted in the more recent decrease in contaminant levels.

Riverine Reach

See above.

Estuary

See above.

River Mouth

Contaminant buildup and increased concentrations in the river mouth are likely to be undetectable. The high-energy wave and tidal actions at the river mouth cause extreme dilution and mixing of sediment particles with potentially associated contaminants. The freshwater and brackish water river plumes are expected to transport up-river contaminants into the near ocean, where they are dispersed by seasonal ocean currents.

2.2.6.2 Disease

Pathogens (viruses, bacteria, and parasites that cause disease) have always been present within salmonid populations in the Columbia River Basin. Little is known about the historical incidence and prevalence of disease, but it is apparent that salmonids have harbored these agents for many years. For example, it has been known since the early 20th century that dogs fed raw salmon frequently became ill and died, although the fluke and its parasitic rickettsia that is the causative agent of salmon-poisoning disease were not identified until the early 1970s.

Riverine Reach

See above.

Estuary

See above.

River Mouth

See above.

2.2.6.3 Suspended Solids

Suspended solids are suspended sediments (sand, silt, and clay) and organic debris transported within the water column near the velocity of the river current. These particles can move long distances before being redeposited. Suspended solids are a factor in salmonid survival for a variety of reasons, including:

- The organic matter is a potential source of biological oxygen demand in the water column.
- The inorganic material may have a detrimental effect on fish through laceration of gills.
- The organic material may be a pathway for transfer of contaminants to fish.
- The associated turbidity may impair feeding by reducing the ability of fish to see prey.
- Suspended sediment can also benefit juvenile salmonids by making them less susceptible to predation.

See Section 2.2.1.1 for a discussion of suspended sediments.

Riverine Reach

Most of the organic matter in suspended solids historically was derived from floodplains and marsh vegetation during inundation from high spring freshets.

Estuary

The organic component of the suspended sediment is a significant source of the detritus that forms the base of the ETM food web (Sherwood, et al., 1990; Simenstad, et al., 1990). Most of the organic matter in suspended solids historically was derived from floodplains and marsh vegetation during inundation from high spring freshets.

River Mouth

At the river mouth and seaward, suspended solids are rapidly diluted and dispersed by the wind and tidally driven currents that are typical of this area.

2.2.6.4 Stranding

Stranding is caused by either water level fluctuations or waves trapping young salmonids that are rearing and migrating in the shallow waters of estuaries and lower rivers.

Riverine Reach

Wave action resulting from strong winds, particularly during storms, had the potential to affect shallow water levels quickly enough to strand fish in shoreline depressions. These depressions may have been more common historically because of the tendency for depressions to form on the land side of obstructions such as large woody debris.

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

2.2.6.5 Temperature and Salinity Extremes

Temperature and salinity extremes can cause physiological stress to fish and other organisms within a confined system, ultimately reducing their chance of survival by making them more prone to disease or predation. Salinity and temperature extremes affect conditions for juvenile salmonid survival as well as upstream migration. Water temperatures greater than 21^{o} C may block migration (Weitkamp, SEI Presentation, 2001; Water Temperature Criteria Technical Work Group, 2001). Temperature and salinity also set the conditions for saltwater adaptation.

Riverine Reach

Salinity extremes are not applicable to the riverine reach. For temperature discussion, see Estuary, below.

Estuary

The extent of salinity intrusion into the Columbia River estuary depends primarily on channel depth, strength of tides, and river flows (Corps, 1999a). Although there are no data regarding the historical limits of salinity intrusion, salinity likely exhibited a significant seasonal range caused by the wide range of seasonal flows (Thomas, 1983). Lower Columbia River temperatures historically may have been relatively cool in the river mainstem because of unfettered river flow and freshets.

River Mouth

See Estuary, above.

2.2.6.6 Turbidity

As described previously, turbidity is a measure of light penetration through water and is a natural part of the habitat to which the young salmonids are adapted. It is a function of the amount of suspended sediment and plankton within the water column. As with suspended sediment, turbidity levels increase with high river flows. Heavy wind and wave activity can also increase turbidity. Turbidity can benefit juvenile salmonids by making them less susceptible to predation.

Turbidity, as it relates to salmonids' ability to survive within the ecosystem, can be positive or detrimental. The reduced visibility caused by fine suspended sediment may be beneficial to juvenile salmonids by hindering predation (Gregory, 1988). However, extremely high levels of suspended sediments that result in turbid conditions can produce sublethal stress (e.g., gill clogging, erosion of gill filaments) or even cause mortality by suffocating in juvenile salmonid populations (Sigler, 1984) (see Section 6.1.3, Suspended Solids).

Riverine Reach

Turbidity levels within the Columbia River historically followed the river's hydrograph closely, rising during spring freshets. Turbidity levels at this time were likely higher than current levels. Turbidity levels during low-flow periods were generally low (Corps, 1999a). The highest turbidity levels occurred during western subbasin winter floods.

Estuary

In addition to the turbidity entering the estuary from the main river, waves and current actions in the shallow flats and channels in the estuary generate turbidity.

River Mouth

See Estuary, above.

2.2.6.7 Predation

Throughout their history, salmonids have been affected by predatory forces. Salmonids have evolved in a dynamic equilibrium along with many types of predators and have responded to selection pressures from those predators. The great advantages of migrating between productive ocean-feeding areas and protected estuarine and freshwater rearing and spawning areas is counterbalanced by the predatory forces responding to the large concentrations of individuals coalescing during migration. Salmonids have adapted to predation pressures in part by maintaining high reproductive rates and developing variable life-history strategies for different populations that result in less concentrated migratory movements for salmonids as a whole throughout the year. Historically, piscivorous mammals, birds, and fish have preyed on salmonids in the near ocean and in the lower Columbia River estuary and freshwater areas.

Riverine Reach

See above.

Estuary

See above.

River Mouth

See above.

2.2.6.8 Entrainment

Entrainment historically was not an issue within the action area.

Riverine Reach

See above.

Estuary

See above.

River Mouth

See above.

2.3 Existing Environmental Conditions

The overall processes and components of the historical lower Columbia River ecosystem addressed in Section 2.2 are the same processes and components that define the existing lower Columbia River ecosystem. However, some of these processes and components have been modified as a result of non-indigenous human activities and long-term natural cycles. Human activities within the Columbia River Basin have tended to reduce the historical variability of the processes and components that characterize the lower Columbia River ecosystem such as the changes in river flows, illustrated previously in Figure 2-2. This section provides an overview of existing conditions by describing the present state of the ecosystem processes and components previously introduced.

2.3.1 Existing Condition for Indicators Affecting Habitat-Forming Processes

Human activities have influenced the physical characteristics of salmonid habitats by modifying habitat-forming processes. This section is a discussion of the current condition of these relevant processes.

2.3.1.1 Suspended Sediment

The average annual suspended sediment load in the Columbia River has been reduced from historical levels by the system of dams and reservoirs in the mainstem and tributaries. The Columbia River is still subject to sporadic large-scale events that affect suspended sediment loads in the action area, as demonstrated by the 1980 eruption of Mount St. Helens. The eruption sent mudflows down the Toutle River to the Columbia and temporarily reduced the channel depth of the Columbia River from 40 feet to 14 feet.

Riverine Reach

The primary factor controlling the suspended sediment volumes in the Columbia River is the large peak flows associated with interior basin spring freshets and the western subbasin winter flood events. These peak flows have been reduced during the latter half of the 20th century by flow regulation at upstream reservoirs. Flow regulation has reduced the 2-year flood peak discharge at The Dalles from 580,000 cfs to 360,000 cfs (Corps, 1999a). These peak flow reductions stem from a variety of factors, including flow regulation, irrigation withdrawal, climate variability, and flood control operations at water storage projects. In addition to reductions in peak flow, the upstream dams have trapped some sediment in the reservoirs. However, a review of pre- and post-flow regulation data relating to suspended sediment revealed no change in the relationship between suspended sediment and river discharge, indicating that there has been no change in the sediment supply over that time period (Eriksen, SEI Presentation, 2001).

A comparison of the suspended sediment data in Figure 2-7 to that in Figure 2-8 shows no significant differences in the suspended sediment/water discharge relationship between Vancouver, Washington (upstream of the Project), and Beaver, Oregon (in the middle of the Project).

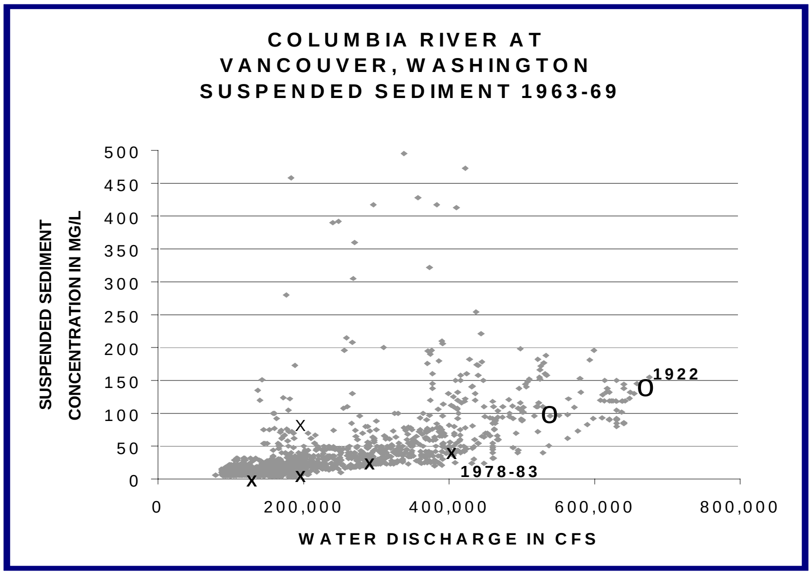
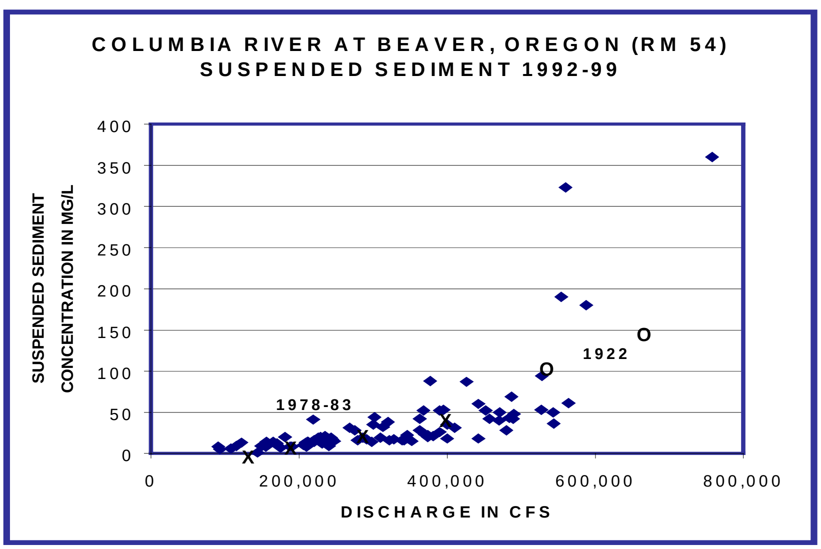


Figure 2-7: Columbia River Suspended Sediment versus River Discharge at Vancouver, Washington (RM 107). [Note: The 1963-69 and 1978-83 data are from the USGS, and the 1922 data are from the Corps.]

Figure 2-8: Columbia River Suspended Sediment versus River Discharge at Beaver, Oregon (RM 54). [Note: The 1992-99 and 1978-83 data are from the USGS. The 1922 data are from the Corps].



The suspended sediment concentrations measured by the U.S. Geological Survey (USGS) at Beaver (RM 53) have been in the ranges of less than 10 milligrams per liter (mg/L) at 100,000 cfs, around 20 mg/L at 200,000 cfs, from 20 to 50 mg/L at 300,000 cfs, and from 20 to 60 mg/L at 400,000 cfs. Those ranges equate to suspended sediment discharges of 2,000 cubic yards per day, 8,000 cubic yards per day, 12,000 to 30,000 cubic yards per day, and 16,000 to 48,000 cubic yards per day, respectively. The Corps has estimated that upstream flow regulation has reduced the average annual suspended sediment load from the historical level of 12 mcy per year to 2 mcy per year. This reduction is a result of the reduced transport potential caused by the lower discharges. The suspended sediment gradation is similar to the historical gradation, consisting mostly of silt and clay size material, with sand constituting less than 30 percent of the load for discharges less than about 400,000 cfs (Corps, 1999a).

Estuary

The 2-mcy-per-year average suspended sediment load in the river is delivered to the upper estuary just downstream of Puget Island. The inflowing suspended sediment is distributed throughout the estuary. Suspended silt and clay particles may remain in the estuary for 1 to 4 months, depending on river and tidal flows (Jay, SEI Presentation, 2001). In the estuary, local erosion and deposition processes can greatly alter the local concentrations. Wind waves and shifting tidal currents can erode material from the estuary's flats and shallow channels, causing increased suspended sediment. Suspended sediment deposition in the estuary still contributes to the creation of shallow water areas that ultimately support vegetation and become marsh or swamp areas, although the reduced sediment load probably has slowed the process. The deposition rate of silt and clay is most likely still in the range of 30 percent of the incoming volume. It is likely that most of the incoming sand is now deposited in the estuary.

River Mouth

The amount of suspended sediment discharge to the Pacific Ocean is unknown. Because of the factors discussed above, it is likely that suspended sediment discharge to the ocean has decreased from historical levels. The average annual suspended sand discharge is probably much less than 0.5 mcy per year.

2.3.1.2 Bedload

The Columbia River's bedload transport has been reduced because of the flow regulation at upstream reservoirs. Flow regulation has reduced the 2-year flood peak discharge from 580,000 cfs to 360,000 cfs (Corps, 1999a). This peak discharge reduction has had an effect on bedload transport because at discharges below 300,000 cfs the bedload transport rate is quite low and sand wave movement is typically only a few feet per day. However, when the flow exceeds 400,000 cfs, the bedload transport rate increases and sand waves can migrate downstream at around 20 feet per day (Corps, 1999a).

Riverine Reach

Sand waves in this reach downstream of Vancouver are generally large, with heights of 6 to 12 feet and up to 500 feet long. The post-regulation average annual bedload transport in the main river channel is estimated to be in the range of 0.1 to 0.4 mcy per year (Corps, 1999a).

Estuary

Bedload transport in the estuary is highly variable, but the rates are not known. Bedload processes in the estuary are influenced by location, bathymetry, river discharge, ocean waves and tidal currents. The main channel between RM 25 and 40 has sand waves comparable to those found in the riverine reach. From RM 25 to around RM 18, the main (south) channel sand waves remain downstream-oriented, but become progressively smaller. Between RM 18 and 12, sand waves are generally small (less than 50 feet long), but can be directed either downstream or upstream, depending on flow conditions. Downstream of RM 12, the main channel sand waves are small and reverse direction with the tide. In the reach around RM 7 to 12, shallower areas adjacent to the main channel have been found to have small, downstream-directed sand waves, even when the main channel sand waves were reversing (CREDDP, 1984).

River Mouth

Current bedload transport to the ocean is unknown. The CREDDP study (1984) found small, reversing sand waves in the entrance during both high- and low-river discharge seasons.

2.3.1.3 Woody Debris

The past century of activities within and adjacent to the lower river floodplains and riparian areas have reduced the amount of large woody debris available to the river and for deposition in shallow water and on tidal flats. During periods of heavy timber harvests before the mainstem dams were constructed, the availability of wood debris in the lower Columbia River increased significantly.

Riverine Reach

The dams upstream of the lower river have created an obstacle to the movement of woody debris into the riverine portion of the project from upstream tributaries. As a result, the net amount of large wood that now moves downstream has decreased. The woody debris within the riverine reach shorelines has the potential to provide structure habitat in shallow shoreline areas for both young salmonids and their potential fish predators, such as bass. However, woody debris does not perform the same channel-forming functions in the large Columbia River channel as it does in the smaller tributary channels.

Estuary

Within most estuarine areas, large woody debris tends to accumulate near the high tide line, where it is available to fish for only brief periods each day near the peaks of the tide cycle. Large woody debris is a common component of the shoreline habitat of forested marsh areas at the upstream edges of estuaries. This large woody debris appears to provide refuge habitat for both young salmonids and some of their fish predators.

River Mouth

Not applicable.

2.3.1.4 Turbidity

Turbidity levels within the Columbia River roughly follow the river's hydrograph, rising during spring freshets and western subbasin winter floods. At any given river discharge there are variations in the observed turbidity. Both the levels of turbidity and variation increase with river discharge.

Riverine Reach

For most of the year, turbidity levels are below 10 nephelometric turbidity units (NTUs). The highest turbidity levels occur during western subbasin winter floods, reflecting the shift in the primary source of streamflow. All the turbidity levels over 20 NTU shown in Figure 2-9 occurred during high winter flows, with the two highest values occurring during the February 1996 flood.

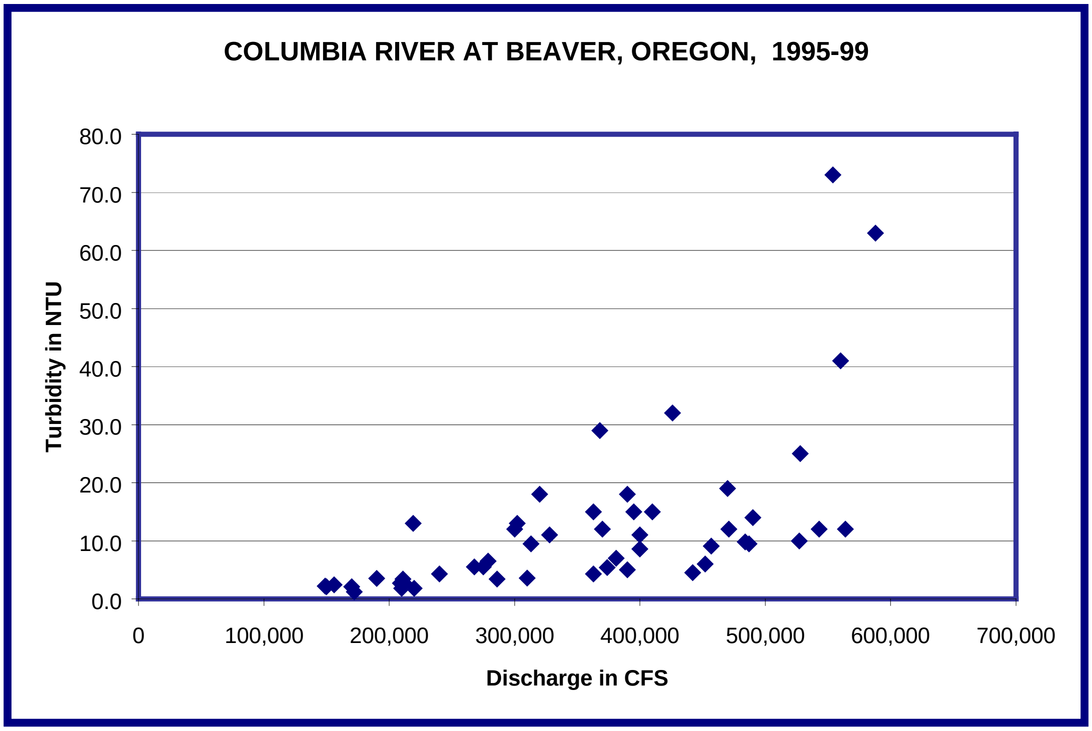


Figure 2-9: Columbia River Turbidity Measured by the USGS at Beaver, Oregon (RM 54)

Estuary

The turbid water from the riverine reach is distributed throughout the estuary. Jay (SEI Presentation, 2001) estimated the fine suspended material that causes turbidity can remain in the estuary for up to 1 to 4 months, depending on tides, river flows, and travel paths. Local erosion and deposition processes can alter the local turbidity levels. Wind waves and shifting tidal currents can erode material from the estuary's flats and shallow channels, causing increased turbidity. Turbidity generated by waves and current actions in the shallow flats and channels in the estuary has probably not changed from historical levels. The tidal hydraulics also create a traveling zone of higher turbidity related to the upstream portion of the salinity wedge. An ETM occurs in both the north and south channels of the estuary. The location of the ETM shifts with the tide and river discharge, similar to the movement of the salt wedge. Researchers have found the ETM in the south channel at various locations between RM 5 and 20 (CRETM-LMER, 2000).

River Mouth

Turbidity levels in the river mouth reach are highly variable and depend on river flow and ocean conditions.

2.3.1.5 Salinity

As stated in Section 2.2.6.5, salinity intrusion into the lower portions of the Columbia River estuary depends primarily on channel depth, strength of tides, and river flows (Corps, 1999a; CREDDP, 1984).

Because of flow regulation within the Columbia River Basin, it is likely that the seasonal variability for salinity intrusion is reduced from historical levels (Thomas, 1983).

Riverine Reach

Salinity intrusion extends only to about RM 40, which divides the riverine area from the estuary. Therefore, salinity is not applicable in the riverine reach.

Estuary

Figure 2-10 shows the range of salinity concentration profiles within the estuary's south (navigation) channel documented by CREDDP during the early 1980s. The maximum salinity intrusion – i.e., salinity greater than 0.5 parts per thousand (ppt) – extended upstream along the bottom of the main channel to near RM 30 during low flow periods. The CREDDP study (1984) also indicates that the upstream limit of salinity intrusion in the shallow waters of Cathlamet Bay was near RM 23 during low flow.

River Mouth

Freshwater extrusion lowers salinity concentrations within the Columbia River plume, but the extent is unknown.

2.3.1.6 Accretion/Erosion

Riverine Reach

Accretion and erosion in this reach have been affected by reductions in sediment inflow, sediment transport potential, and overbank flooding. Levee construction and upstream flow regulation have reduced flooding frequency, which in turn has reduced sediment accretion in the overbank areas.

There may be slightly more accretion at the mouth of the Sandy River (RM 121 to 123) as a result of the reduction in the Columbia River's ability to erode and transport sediment (see Section 2.2.1.6).

Flow regulation has likely reduced sediment inflow from the Willamette and Cowlitz Rivers, except for the 1980 eruption of Mount St. Helens. That eruption caused a large volume of sediment, 50 to 100 mcy, to be deposited in the Columbia River at the mouth of the Cowlitz River. Most of that sediment was not transported downstream because much of it was dredged from the river.

River flows continue to shift sediment around within the river channel. Shoals persistently form in the navigation channel, and significant accretion might occur if dredging was not performed. Shoreline erosion continues at sandy beaches created by past disposal. Shoreline erosion probably occurs more slowly than it would without flow regulation because high river stages occur less frequently.

Estuary

The Corps has estimated that the average annual deposition rate in the estuary has decreased from a historical level ranging from 2 to 5 mm per year. The Corps has estimated the current average accretion rate at 1 mm per year. Locally, accretion and erosion rates may be much higher and could change from year to year. Eriksen (SEI Presentation, 2001) found that the north channel between RM 6 and 7 had infilled up to 20 feet between 1982 and 2000.

Figure 2-10: Salinity Sections in the Main Navigation Channel

River Mouth

The accretion and erosion patterns in the river mouth reach have been altered from historical times. The entrance channel is now maintained to a minimum depth of -55 feet MLLW by annual dredging and the presence of the jetties. Peacock Spit has been eroding since around 1940. Recent erosion has also occurred in the entrance between the two jetties.

2.3.1.7 Bathymetry

There has been a great deal of change in the river bathymetry since the turn of the 20th century. Navigation development has deepened the channel in all three reaches, and the riverine and entrance channels have also been narrowed.

Riverine Reach

The riverbed between RM 106 and 146 remains generally broad and shallow. A shallow-draft navigation channel (currently maintained at -17 feet CRD) extends through the reach. Below RM 106, the bathymetry of this reach has changed over the past 100 years. The depth of the thalweg has increased and portions of the river are narrower. The thalweg is now consistently more than 40 feet deep, with short reaches of over 70 feet. Dredging disposal has been used to create shoreline and in-water fills that have narrowed the river and created small side channels. These fills exist throughout the riverine reach. The riverbed is still sandy and covered with sand waves. The riverbed side-slopes remain generally flat, with slightly steeper slopes near shorelines protected by pile dikes. The bathymetry shifts more slowly because of the reduction in high discharges from flow regulation. New shallow side channels flow around islands that were created by past disposal, such as those at RM 98, 95, 81, 76, and 64 to 60.

Estuary

The estuary still contains varying bathymetry. The main channel still crosses from the north to south side of the estuary between Harrington Point and Tongue Point. The remnants of the old main channel still exist along the north side of the estuary upstream to about RM 20. Shallow, tidal, and subtidal flats occupy the central part of the estuary between those two large, deep channels. Several small channels cut the shallow flats. There are numerous channels around the many islands in Cathlamet Bay. The limited shoreline disposal in this reach has had little effect on the bathymetry. Disposal has created Rice, Miller Sands, and Pillar Rock Islands in areas that were once shallow water. Because the frequency and magnitude of high-flow events in the lower Columbia River has been reduced by flow regulation within the basin, changes in estuary bathymetry occur at a much slower rate than was historically the case.

River Mouth

The entrance channel was deepened by dredging to -48 feet MLLW in 1956-57 and to -55 feet MLLW in 1984. The entrance channel is now maintained to a minimum depth of -55 feet MLLW by annual dredging and the jetties. Peacock Spit has been eroding since around 1940. Dredged material disposal has replaced some of the eroded sediment and formed two separate mounds.

2.3.2 Existing Condition of Habitat Types

Changes in flow regulation and shoreline development and diking have changed the lower river and the habitat types that are important to listed salmon and trout species. This section will discuss the changes that have occurred to these habitat types and the forces that create and nourish them. Figures 2-11 through 2-17 have been included to give a general understanding of the existing land covers for RM 106.5 to RM 3, which provides a context for the habitat changes that have occurred.

2.3.2.1 Tidal Marsh and Swamp Habitats

The existing tidal marsh and swamp habitats of the lower Columbia River are the result of past habitat-forming processes and are maintained by the same processes occurring now.

Riverine Reach

Diking and flow regulation have led to significant changes in the amount and location of tidal marsh and swamp habitats within the lower Columbia River. Highways, railroads, and diking have contributed to narrowing and confining of the river to the existing location. Diking has resulted in confinement of 84,000 acres of floodplain that likely contained large areas of tidal marshes and swamps. Between the mouth of the Willamette River and the mouth of the Columbia River, diking and other activities have resulted in an estimated loss of about 52,000 acres of wetland/marsh and 27,000 acres of forested wetland since the 1870s (Graves, et al., 1995). Much of this land is now in agricultural use. Riparian forests (cottonwood and ash-broadleaf forest) declined by approximately 14,000 acres through conversion of land to agriculture and upland development.

The remaining tidal marsh and swamp habitats currently are located in a narrow band along the river banks and around undeveloped islands. Side channel and backwater habitats occur in large islands such as Wallace, Crims, Willow Grove, Fisher, Hump Walker, Lord, Howard, Cottonwood, Sandy, Martin, Burke, and Sauvie Islands (see Figures 2-11 to 2-15).

Federal and state wildlife management areas are located in the riverine reach. These provide wetland and riparian forest habitat for wintering waterfowl, raptors, shorebirds, furbearers, and other wildlife species. The management areas include Ridgefield National Wildlife Refuge and Shillapoo Wildlife Management Area in the Vancouver lowlands, and Sauvie Island Wildlife Management Area in Oregon.

Estuary

In the estuary, tidal marshes have decreased in area from 16,180 acres in 1870 to the current 9,200 acres (a decrease of approximately 43 percent). Tidal swamps in the estuary have decreased from 32,020 acres to 6,950 acres (a decrease of approximately 77 percent) over the same period (Thomas, 1983). Losses are attributed primarily to diking and filling. Erosion accounts for a very small amount (about 150 acres) of loss.

While there has been a net loss of tidal marsh and swamp habitat since 1870, new marsh and swamp areas are continuing to form within the estuary. This is occurring because disposal of dredged material has created new shoreline areas that have colonized by vegetation and because natural accretion within shallow areas has combined with colonization by bulrush (*Scirpus* spp.) and other marsh vegetation (Thomas, 1983).

Figure 2-11: Reach 1 Land Cover RM 98-106.5

Figure 2-12: Reach 2 Land Cover RM 84-98

Figure 2-13: Reach 3 Land Cover RM 70-84

Figure 2-14: Reach 4 Land Cover RM 56-70

Figure 2-15: Reach 5 Land Cover RM 40-56

Figure 2-16: Reach 6 Land Cover RM 29-40

Figure 2-17: Reach 7 Land Cover RM 3-29

River Mouth

No tidal marshes or swamps were noted in this area in the 1870s. Since then, about 250 acres of tidal marshes have been added in the vicinity of Point Adams through natural vegetation colonization (Thomas, 1983). The primary reason for this increase has been removal of wave action in certain areas of the river mouth by construction of jetties, which has allowed colonization by vegetation in shoreline areas. Figures 2-18a and 2-18b show the results of a CREDDP survey (1984) of the estuary for habitat types, including marsh and swamp locations.

2.3.2.2 Shallow Water and Flats Habitat

Shallow water and flats habitat occurs along the margins of shallow water areas of the lower Columbia River, which are scattered throughout the action area. This habitat type is concentrated in the estuary and downstream portions of the riverine reach.

Riverine Reach

See above.

Estuary

Thomas (1983) estimated that shallows and flats have increased by approximately 4,130 acres since 1870.[12] Shallow water and flats habitat has increased throughout most of the estuary (Sherwood, et al., 1990). In particular, significant shoaling has occurred in Cathlamet and Baker Bays, which, in the case of Baker Bay, led to the creation of 3,620 acres of shallow water and flats habitat (Thomas, 1983).

River Mouth

Shallow water habitat at the river mouth is decreasing because jetties that have been constructed have reduced or removed much of the wave energy that previously prevented formation of shallow water areas through erosion. Sand deposited in this area now forms sand dunes in areas that were formerly shallows and flats (Thomas, 1983).

[12] Thomas defines the estuary as that portion of the river to RM 46. As stated previously, the estuary is defined as that portion of the river from RM 3 to RM 40 for purposes of this BA.

Figure 2-18a: Habitat Types (Sheet 1 of 2)

Figure 2-18b: Habitat Types (Sheet 2 of 2)

2.3.2.3 Water Column Habitat

For the Columbia River, water column habitat currently serves a particularly important function as the carrier of imported phytoplankton and microdetritus from upriver to the lower Columbia River and estuary. It also serves as a migratory corridor for adult and juvenile salmonids.

Riverine Reach

See Estuary, below.

Estuary

As a result of the long-term changes in tidal marsh and swamp habitat, and the reduced availability of macrodetritus, the water column habitat contributes a greater proportion of organic matter to the food web in the system than occurred historically. The salinity mixing zone, which is associated with the ETM, is an important part of the water column habitat. This zone is a highly productive feeding area for zooplankton and benthic and epibenthic organisms (Simenstad, et al., 1994). The location of ETM moves up and down the estuary naturally. Because of flow regulation by mainstem dams, the ETM is believed to move around the estuary less than it did in the past.

River Mouth

See Estuary, above.

2.3.3 Existing Condition for Indicators Affecting Habitat Primary Productivity

This section addresses the current status of plant growth and production in the respective habitats and how the habitats' primary productivity within the lower Columbia River has changed in response to habitat modification. As discussed previously in Section 2.2.3, various plant species in lower Columbia River habitats are the primary producers that capture solar energy in plant biomass and form the base of the salmonid food web. As in the discussion of historical habitat primary productivity, this section will address resident and imported phytoplankton (water column habitat), benthic algae (shallow water and flats habitat), and the plant growth associated with tidal marsh and swamp areas. The changing conditions have shifted the primary producers from a marsh-based macrodetrital food web to a microdetrital food web. As before, the necessary process inputs of light and nutrients will also be discussed. Figures 2-19a and 2-19b show the results of CREDDP's 1984 survey of primary productivity locations with the estuary.

2.3.3.1 Light

Primary productivity within the shallow water and flats and water column habitats depends in part on the amount of light energy fixed in the ecosystem. Light penetration can be decreased by turbidity.

Riverine Reach

See Estuary, below.

Estuary

Flow regulation and sediment trapping associated with the dams upstream of the lower Columbia River have altered the annual average suspended sediment load in the estuary. This change has resulted in somewhat lower turbidity levels than occurred historically. Nonetheless, the lower Columbia River is generally still quite turbid, with a productive photosynthesis layer that ranges from 1.5 to 4.5 meters, depending on the season and location (CREDDP, 1984). At these depths, light input can be a limiting factor for the primary production of benthic algae and phytoplankton within the lower Columbia River (CREDDP, 1984).

River Mouth

See Estuary, above.

2.3.3.2 Nutrients

Riverine Reach

See Estuary, below.

Estuary

Organic matter cycling from tidal channel tributaries to the main river channel likely continues to be a major source of nutrients within the estuary. However, substantial reductions in the tidal marshes and swamps in all sections of the action area probably have substantially reduced the contributions of this material to nutrient levels in the system. Within the Columbia River Basin, projected calculations indicate an 84 percent decline in macrodetritus input when compared with historical levels (Sherwood, et al., 1990). While this would suggest a decrease in the input from the breakdown of macrodetritus, increases from upstream sources of nitrogen or phosphates appear to provide adequate nutrient input. With the exception of occasional short periods in the late spring and summer, nutrient supply is not a limiting factor in primary productivity within the estuary (CREDDP, 1984).

Substantial loss of marsh macrodetritus, coupled with an increase in phytoplankton production in the system and an increase in imported plankton, suggests a shift from a dominance of macrophyte-derived nutrients to plankton-derived nutrients. Remineralization of nutrients from macrophyte biomass generally requires more time and energy than does that from phytoplankton. Furthermore, macrophyte detritus enters estuarine systems in fall and winter as opposed to spring and summer for phytoplankton (Thom, 1984). Consequently, the timing of the release of nutrients to the water column would have changed compared with historical conditions.

River Mouth

See Estuary, above.

Figures 2-19a: Primary Producers (Sheet 1 of 2)

Figures 2-19b: Primary Producers (Sheet 2 of 2)

2.3.3.3 Imported Phytoplankton Production

Riverine Reach

Most of the phytoplankton within the lower Columbia River are freshwater species imported from upstream locations (CREDDP, 1984) (Figure 2-20). Currently, imported freshwater phytoplankton are composed primarily of planktonic diatoms produced behind the mainstem dams (Sherwood, et al., 1990). Phytoplankton, the primary component of the current lower Columbia River food webs (Bottom and Jones, 1990), serve as the energetic base on which zooplankton, benthic fauna, and epibenthic organisms feed. However, because phytoplankton and the microdetritus produced from it are found within the water column, they tend to support a pelagic food web that is less accessible to juvenile salmonids.

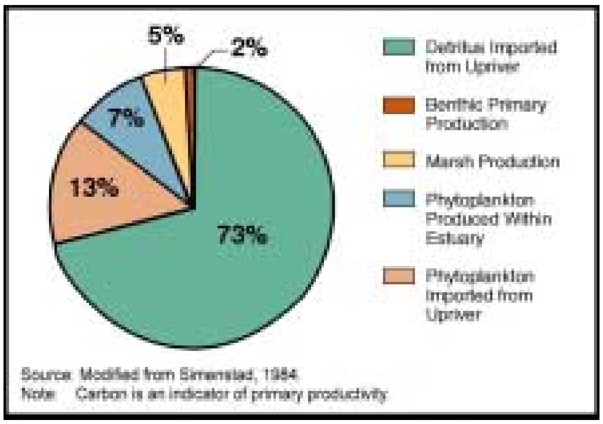


Figure 2-20: Carbon Sources in the Estuary

Estuary

Freshwater phytoplankton species generally dominate collections made in the estuary. However, during low-flow periods in summer, marine species can dominate collections in the estuary (Small, et al., 1990).

As stated in Section 2.2.3.3, estimates suggest that the annual input of imported phytoplankton to the estuary (riverine and estuarine sections) has increased on the order of seven times, going from 9,000 metric tons of carbon to 61,440 metric tons of carbon (Sherwood, et al., 1990). Production of imported phytoplankton in reservoirs above the dams accounts for the massive increase in input to the lower Columbia River system. In addition, production of imported phytoplankton in the lower Columbia River is enhanced by the increase in light penetration related to a reduction in the suspended detrital material, decreased vertical mixing, and increased retention time (Sullivan, et al., 2001).

River Mouth

See Estuary, above.

2.3.3.4 Resident Phytoplankton Production

Riverine Reach

Indirect evidence suggests that resident phytoplankton contribute much less proportionally to the food web than imported phytoplankton in the riverine portion of the action area. See Sherwood, et al. (1990) regarding fluvial import of microdetritus.

Estuary

Resident phytoplankton production does not currently appear to be a significant part of the primary production within the lower Columbia River (see Figure 2-20). An existing theory to explain this is that the low level of phytoplankton production within the estuary is a result of the relatively quick flushing time associated with the lower river (CREDDP, 1984). Because the freshwater phytoplankton are moving quickly through the lower river estuary, it is suggested that they cannot build up concentrated communities before being exposed to lethal salinity levels. The current flushing time is 1 to 5 days, depending on flow and tidal conditions (CREDDP, 1984).

Although resident phytoplankton production is not significant, increased light penetration under post-flow regulation conditions (e.g., reduced suspended detrital matter, lower vertical mixing rates) may have resulted in an increase in resident phytoplankton production (Sullivan, et al., 2001), although the amount of change is unquantified.

River Mouth

See Estuary, above.

2.3.3.5 Benthic Algae Production

Benthic algae occur throughout the action area. As with phytoplankton, changes in salinity and light will affect their productivity and distribution.

Riverine Reach

The most important primary producers within the riverine reach, as well as in the estuary, are microalgae distributed throughout the lower river on the sediments of shallow subtidal and intertidal flats (Thomas, 1983; McIntire and Amspoker, 1984).

Estuary

Benthic algae production within the estuary has always tended to be limited to shallower areas (above the MLLW) and sheltered areas such as Youngs and Trestle Bays (Thomas, 1983; CREDDP, 1984). Indications are that the percentage of these habitat areas has actually increased by approximately 7 percent from 1870 levels, including 3,620 acres in Baker Bay (Sherwood, et al., 1990; Thomas, 1983).

Benthic algae production is not believed to have changed substantially from historical conditions (Sherwood, et al., 1990), although lower turbidity may improve light conditions and enhance productivity. McIntire and Amspoker (1986) found a strong correlation between light and benthic algae production and surmised that clearer water would result in greater benthic algae production.

Benthic microalgae likely enter the particulate organic matter pool used by benthic infauna and epibenthic invertebrates. These are, in turn, important to the food web of salmonids (Simenstad, et al., 1990).

Sherwood, et al. (1990), estimated that benthic microalgae production in the fluvial through river mouth portion of the lower Columbia River has declined approximately 15 percent (from 1,825 to 1,545 metric tons of carbon) since before 1870. This loss may be related to a general decline in shallow flats and channels associated with marshes that were diked or filled. Sherwood, et al. (1990), suggest that possible reasons for this decrease are a reduction of the tidal prism, a net increase in sediment in the estuary, and reduction in river flow, resulting in:

- Decreased mixing

- Increased stratification
- Altered response to tidal forcing
- Decreased salinity intrusion length and transport of salt into the estuary

Production of benthic microalgae is vital to the current lower Columbia River salmonid food web because microalgae serve as the primary food source for the benthic infauna (e.g., *Corophium*) currently preyed on by juvenile salmon.

River Mouth

See Estuary, above.

2.3.3.6 Tidal Marsh and Swamp Production

As discussed in Section 2.3.2.1, diking and flow regulation have led to significant changes in the amount and location of tidal marsh and swamp habitat within the lower river. As these habitat areas have been reduced, the total amount of primary production has decreased, assuming similar area production rates for similar marsh and swamp types (Thomas, 1983).

Riverine Reach

Current tidal marsh and swamp production is lower than historical levels in the riverine and estuarine portions of the lower Columbia River. The decline is proportional to the loss in area of tidal marsh and swamp habitat described in Section 2.3.2.1. About 250 acres of tidal marshes have been added through natural colonization since the 1870s in the vicinity of Point Adams (Thomas, 1983). Predictably, a very slight increase in tidal marsh production has been associated with this small increase in this type of habitat in the river mouth. Diking has effectively cut off much of the historical floodplain throughout the riverine reach. Isolation of the river from the historical floodplain has likely reduced the amount of macrodetrital input to the system.

Annual production by marshes in the riverine (fluvial) section of the study area averaged 401 grams of carbon per square meter. Rates of marsh production in the post-development period are probably similar to pre-development conditions. However, because of the decline in marsh area as a result of diking and filling, total production throughout the study area has declined dramatically. Based on data from the estuary and fluvial systems, total emergent plant production has declined an estimated 72 percent (62,629 to 11,324 metric tons of carbon per year) since before 1870 (Sherwood, et al., 1990).

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

2.3.4 Existing Condition for Indicators Affecting Food Web

There has been a shift in the available plant life within the river. Imported microdetritus has increased substantially, while tidal marsh and swamp vegetation and macrodetritus have declined. This has led to a shift within the food web for the lower river.

This section moves into a discussion of the shift that has occurred within the food web as a result of the primary production occurring within the relevant habitat areas. This section focuses on the current state of the food sources that the salmonids eat.

2.3.4.1 Deposit Feeders

Riverine Reach

See Estuary, below.

Estuary

Although deposit feeders historically played a large role in the estuarine food web for salmon and trout, the food web has shifted to emphasize suspension-feeding copepods associated with the ETM zone. This is in part because of the reduction in available tidal marshes and swamps and freshwater wetlands within the system, which supplied the macrodetritus that, in turn, supported the deposit feeders in the system (Sherwood, et al., 1990).

River Mouth

See Estuary, above.

2.3.4.2 Mobile Macroinvertebrates

Riverine Reach

See Estuary, below

Estuary

In freshwater and brackish habitats, mobile macroinvertebrates, particularly mysids, currently provide an important juvenile salmon food source (Simenstad and Cordell, 2000; Miller and Simenstad, 1997). However, as with other benthic and epibenthic food sources within the estuary, there has been a reduction in availability and productivity. Accordingly, the emphasis has shifted toward a microdetritus-based food web (Sherwood, et al., 1990).

River Mouth

See Estuary, above.

2.3.4.3 Insects

Riverine Reach

See Estuary, below.

Estuary

Many insect species feed directly on the vegetation in freshwater wetlands and tidal marshes and swamps. As these habitat areas have been reduced (approximately 43 percent of tidal marsh habitat and approximately 77 percent of the historical tidal swamps), so too has the primary production from these areas (Thomas, 1983). While emergent insects still provide an important food source for juvenile salmon in the estuary (Simenstad and Cordell, 2000; Miller and Simenstad, 1997), the relative importance of insects' role in the food web is believed to have diminished.

River Mouth

See Estuary, above.

2.3.4.4 Suspension/Deposit Feeders

Riverine Reach

See Estuary, below.

Estuary

Suspension/deposit feeders are benthic and epibenthic organisms that feed on or at the interface between the sediment and the water column. Although the benthic/epibenthic food web, which was a prominent feature of the historical lower Columbia River ecosystem, no longer produces as varied or as rich a food web, the food it does produce is vital to juvenile salmonid survival (Sherwood, et al., 1990). The primary suspension/deposit feeders used by salmonids in the estuary are *Corophium salmonis and Neomysis mercedis* (McCabe, 1997).

River Mouth

See Estuary, above.

2.3.4.5 Suspension Feeders

Riverine Reach

The discussion of primary productivity in the lower river habitats showed that primary productivity has shifted toward the phytoplankton and microdetritus that support suspension feeders. Many of these suspension feeders are planktonic (i.e., drifting passively with the current – e.g., *Daphnia pulex*).

Estuary

The most productive group of zooplankton suspension feeders are estuarine (e.g., *Neomysis mercedis*).[13] These zooplankton tend to dwell in the bottom waters of the estuary, which often has an upriver flow (CREDDP, 1984). The tendency is for the zooplankton to concentrate at the ETM, which is where the upriver saline flow mixes with the freshwater downstream flow. The ETM is rich with dead and dying phytoplankton that are unable to tolerate the salinity of the ETM. This provides plentiful food for the estuarine zooplankton. Because flow regulation has eliminated the high flows that tend to override the upstream saline bottom current, the estuarine zooplankton tend to remain in the estuary and multiply (CREDDP, 1984). This dynamic has turned the ETM, with its suspension feeding base, into the richest, most abundant part of the modern food web in the estuary (Bottom, et al., 2001). However, this food web tends to support pelagic species such as anchovy, herring, American shad, and longfin smelt. While some

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[13] Estuarine zooplankton are adapted to low salinity levels, but will typically tolerate freshwater. The other types of zooplankton in the lower Columbia River are marine (e.g., *Archeomysis grebnitzkii*) and freshwater (e.g., *Daphnia pulex*).

of these species may be prey for older salmon on the way out of the estuary, they do not benefit ocean-type juvenile salmonids, which tend to stay in shallow water areas (Bottom and Jones, 1990).

River Mouth

See Estuary, above.

2.3.4.6 Tidal Marsh Macrodetritus

Riverine Reach

See Estuary, below.

Estuary

As pointed out in Sections 2.3.2.1 and 2.3.3.6, habitat areas in the estuary have been reduced by approximately 43 percent for tidal marsh habitat and approximately 77 percent for tidal swamps (Thomas, 1983). As also pointed out in the discussion of tidal marsh and swamp primary productivity, the reduction in habitat area has caused a concurrent reduction in the overall amount of tidal marsh and swamp plant production in the estuary. Because there are fewer tidal marsh and swamp plants in the estuary, there is less source material for macrodetritus. The reduction in macrodetritus primarily affects the benthic communities that were previously adjacent to the tidal marsh and swamp areas. The impact to the benthic communities has played a part in shifting the estuary away from a benthic food web and towards a pelagic food web (Sherwood, et al., 1990).

River Mouth

See Estuary, above.

2.3.4.7 Resident Microdetritus

Riverine Reach

See Estuary, below.

Estuary

As discussed in Section 2.3.3.4, little primary production occurs within the water column of the lower Columbia River. Figure 2-20 shows the relative production of resident phytoplankton compared with the amount of imported phytoplankton and detritus that enters the system from upstream. This figure graphically illustrates that resident phytoplankton is likely to be of limited importance in the estuarine food web. The input of microdetritus from benthic sources is still important, but the relative input of benthic microdetritus is low, as also indicated in Figure 2-20.

River Mouth

See Estuary, above.

2.3.4.8 Imported Microdetritus

Imported microdetritus is mostly derived from algal production upriver, including that produced above dams, and is important for suspension feeders and suspension/deposit feeders.

Riverine Reach

See Estuary, below.

Estuary

Imported microdetritus in the estuary is composed primarily of phytoplankton carried downstream from the reservoirs into the lower river where they die when they encounter saltwater (CREDDP, 1984). As Figure 2-20 shows, detritus imported from upriver is by far the greatest contributor of organic carbon to the estuary.

Because of the loss of tidal marshes and swamps and freshwater wetlands in the lower river and the associated loss of macrodetritus input, there has been a significant shift in the estuary to a microdetritus-based food web. There is some dispute about whether such a food web is capable of properly supporting the full array of salmonid life stages (Bottom and Jones, 1990; Sherwood, et al., 1990). The concern is that juvenile salmonids do not feed on the pelagic[14] organisms supported by a microdetrital food web. An additional concern is that the microdetrital material does not provide an adequate food resource to the benthic invertebrates that juvenile salmonids feed on.

River Mouth

See Estuary, above.

2.3.5 Existing Conditions for Indicators Affecting Growth

Attaining adequate growth is vital to the survival of juvenile salmon and trout. To grow, the fish not only need thriving food resources, but also access to those resources. Section 2.3.4 described the changes that have taken place in the lower Columbia River food web. This section is a discussion of the accessibility of those areas to the fish. The ecosystem components that are relevant to ensuring that the fish have sufficient access to food to provide adequate growth opportunities include:

- Habitat complexity/connectivity/conveyance
- Velocity field
- Bathymetry and turbidity
- Feeding habitat opportunity
- Refugia
- Habitat-specific food availability

The existing conditions within the Columbia River Basin for these important growth factors are discussed in this section.

2.3.5.1 Habitat Complexity, Connectivity, Conveyance

Flow regulation, beginning in the 1930s, and diking of the floodplains, starting in the late 1800s, have eliminated the seasonal inundation of margin and floodplain areas, which has reduced the complexity of this habitat. Although there are no particular barriers to passage that affect the remaining habitat, connectivity among habitats may be affected by a reduction in the size and number of corridors connecting the habitat areas.

[14] Organisms living within the water column habitat.

Riverine Reach

See Estuary, below.

Estuary

The lower Columbia River has lost much of the habitat complexity that it had historically, primarily as a result of diking and filling within the estuary (Thomas, 1983).

River Mouth

See Estuary, above.

2.3.5.2 Velocity Field

Velocity fields vary up and down the water column and across the river channel. Low velocities can almost always be found near the riverbed and along the shoreline. Shallow flats and estuarine side channels provide an abundance of low-velocity fields.

Riverine Reach

See Estuary, below.

Estuary

Although flow regulation and diking have reduced access to remaining low-velocity marshland and tidal channel habitat, that same flow regulation has reduced overall flow volume and velocity in the lower Columbia River, which promotes this type of habitat. In addition, while there are fewer tidal marshes to provide low-velocity habitat, there has been an increase in shallow water and flats habitat, which typically has lower flow velocities than the deeper channel areas (Thomas, 1983).

River Mouth

See Estuary, above.

2.3.5.3 Bathymetry and Turbidity

Bathymetry and turbidity are fairly consistent throughout the riverine reach, but both are highly variable in the estuary.

Riverine Reach

See Estuary, below.

Estuary

Because salmonids are visual predators, turbid waters may limit their ability to see prey, and uneven bathymetry may hide the prey from their sight. While the bathymetry and turbidity of the modern river are still highly variable, they are much less so than historically (see Section 6.1.8, Tidal Marsh and Swamp Habitat).

Evidence of the effect of turbidity on salmonid feeding patterns is suggested by dietary changes in juvenile salmonids following the eruption of Mount St. Helens in 1980. Following the eruption, the benthic amphipods commonly recorded in salmonid stomach analyses were supplanted by insects and cladocerans (McCabe, et al., 1981; Emmett, 1982; Kirn, et al., 1986). This shift in diet suggests that benthic amphipods either became less available or were less visible during very high turbidity.

River Mouth

See Estuary, above.

2.3.5.4 Feeding Habitat Opportunity

Habitat opportunity refers to those physical characteristics that affect access to geographical locations important to particular fish needs. "Feeding habitat opportunity" refers specifically to the ecosystem's ability to provide access to important feeding habitats (see Section 2.2.5.4).

Riverine Reach

The significant reduction in tidal marsh habitat and the diking of floodplains that occurred in the late 1800s and early 1900s substantially reduced the variety of feeding habitat available.

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

2.3.5.5 Refugia

Refugia is an important aspect of the growth of juvenile salmonids (see Section 2.2.5.5, Refugia).

Riverine Reach

Significant areas throughout the riverine reach have been diked; as a result, areas that would have provided cover and rearing habitat have been lost. Consequently, overall refugia has been reduced in the riverine portion.

Estuary

The lower river has 7 percent more shallow water habitat currently than it had historically. These shallow water habitats provide low-velocity fields, allowing for energy conservation for juvenile salmonids. As in the riverine reach, significant areas have been diked. Diking restricts the amount of potential refugia provided by floodwater spillover into tidal marsh areas. It also prevents high flows from extending the margins of the estuary outward, which would increase the shallow water areas available for refuge (Bottom, et al., 2001).

River Mouth

See Estuary, above.

2.3.5.6 Habitat-Specific Food Availability

Riverine Reach

The food web in the action area is based in large part on detritus. As described in Section 2.2.3, detritus sources may include emergent plants from tidal marshes, benthic algae, resident phytoplankton in estuarine waters, and fluvial inputs of imported phytoplankton from upstream sources. Tidal marsh loss in the estuary, water impoundment in the upper river, and reduced flooding and flow variation have all contributed to reduced recruitment of macrodetritus; consequently, microdetritus has become the base of the food web. This material originates primarily from the reservoirs behind the mainstem dams above the action area.

Estuary

The statement above regarding the riverine reach applies to the estuary as well. In the estuary, microdetritus tends to accumulate within the ETM (CREDDP, 1984). Juvenile salmonids benefit less from good food sources in the water column of the central estuary because their habitats generally are peripheral flats and marshes.

River Mouth

See Estuary, above.

2.3.6 Existing Conditions for Indicators Affecting Survival

The number of ecosystem factors that have an important effect on the ability of salmon and trout to survive within the Columbia River Basin has increased since human development in the basin began. Historical factors for survival included predation, stranding, disease, and the effects of contaminants, suspended sediments, and temperature and salinity extremes on salmon and trout. Issues like disease, which were not historically issues of concern, have become more significant in the present. In addition, entrainment of fish and contamination, which were not historical survival issues, are now issues for discussion. This section addresses the changes that have occurred to the various survival factors subsequent to human development in the basin.

2.3.6.1 Contaminants

Current levels of sediment contamination from polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and dichlorodiphenyl trichloroethane (DDT) and its metabolites are discussed in Appendix B. Within a short-term historical perspective, two of the contaminants assessed, PCBs and DDT, were much more prevalent historically (1960s and early 1970s) than they are today and their concentrations are continuing to decline gradually since 1972, when use of DDT was banned. Apart from increased sediment contamination associated with point sources of pollutants, the most notable feature of the sediment contamination in the lower Columbia River is its uniformity. This reflects the non-point source origin of contaminants and the high energy of the Columbia River, which tends to uniformly mix contaminants within the main river channel, resulting in little difference upstream to downstream. Differences in contamination are greatest when contamination in the navigation channel is compared to that in the shoreline sediments. Shoreline sediments, especially in areas where fine particulates deposit, contain higher concentrations of contaminants because they contain higher concentrations of the organic matter to which the contaminants sorb.

The physical and chemical test results for sediment in the Columbia River are discussed in Appendix B.

Riverine Reach

Because PCBs and DDT are distributed widely via atmospheric transport and non-point sources, such as soils and sediments representing large reservoirs in which these contaminants persist, the concentrations found in the environment apart from point sources of pollution do not change greatly in the lower Columbia River. Use of DDT peaked in the 1960s, then slowly declined since it was banned in December 1972. Correspondingly, use of PCBs peaked in the 1970s, then it was abruptly banned in 1977. Because both of these contaminants break down extremely slowly in the environment, their concentrations have declined very gradually over the past 25 years.

PAHs differ from the organochlorine hydrocarbons in that they are generated by internal combustion engines and are derived from natural sources (e.g., forest fires). Their concentrations have been increasing over time due to population and economic expansion. They represent a broad group of contaminants that range from ones that are rapidly broken down in the environment (e.g., benzene, naphthalene) under most conditions to those that tend to persist in some circumstances, such as benzo-a-pyrene in anaerobic sediments.

Overall contamination in the riverine reach reflects the increased number of sources from municipalities and industries. Contamination in the navigation channel is negligible due to extremely low organic carbon content.

Estuary

Contamination in the estuary is less than in the riverine reach because there are fewer and smaller urban and industrial sources of contamination (see Appendix B). Increased dilution of both water and sediment from tidal mixing also lowers contaminant concentrations. As discussed above, the navigation channel contains negligible contamination.

River Mouth

Contamination is lowest in the river mouth, principally because there are no sources other than transient shipping and the influence of upstream sources is greatly diluted by tidal mixing with ocean water.

2.3.6.2 Disease

The number and types of pathogens occurring in Columbia River salmonids have increased in recent years through the introduction of hatchery fish and the movement of fish and water among river basins. The recent introduction of whirling disease to Oregon waters is an example. Diseases in salmon within the Columbia River Basin have been documented for the past half-century.

Riverine Reach

See above.

Estuary

See above.

River Mouth

See above.

2.3.6.3 Suspended Solids

Riverine Reach

See Estuary, below.

Estuary

Shoreline dikes and levees, as well as the hydroelectric dams, have reduced the amount of suspended solids in the river. While the lower turbidity associated with reduced suspended sediments means that salmonids can identify prey more easily, it also means that they can be preyed on more easily.

In addition to the effects on prey and predation, the role of suspended solids in food production has changed from historical conditions. The organic material that provided the base of the food web is now composed of phytoplankton from the upstream reservoirs rather than the recruited organic material from inundated floodplains and marshes (Sherwood, et al., 1990).

River Mouth

See Estuary, above.

2.3.6.4 Stranding

The natural processes historically influencing the susceptibility of juvenile salmonids to stranding in the lower Columbia River are the same physical processes that currently exist. However, upstream peaking flow fluctuations and ship wakes, which were not factors historically, are additional contributors to modern stranding.

Riverine Reach

River flow in the study area is significantly altered by the operation of the upstream reservoirs. Flow is determined by electricity demand, so flows rise and fall to meet that demand. Studies have shown that this fluctuation can strand juvenile fish both in the pools above the dams and in the lower river. In addition, the wakes of ships navigating the lower river can strand fish on exposed sand or behind structures on the beach.

A 1977 report listed observations of stranded juvenile salmonids from both peaking flows and ship wakes. The total mortality rates for observation sites between the mouth of the Columbia River and the Cowlitz River were 145,003 chinook, 1,359 coho, 4,771 chum, and 537 steelhead from February to July 1975 (Bauserfeld, 1977).

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

2.3.6.5 Temperature and Salinity Extremes

River temperature within the basin varies depending on flow, season, and climate conditions. As stated in Section 2.3.1.5, salinity intrusion into the lower portions of the Columbia River estuary depends primarily on channel depth, strength of tides, and river flows (Corps, 1999a; CREDDP, 1984).

Riverine Reach

Salinity intrusion extends only to about RM 40, which divides the riverine reach from the estuary; therefore, salinity is not applicable in the riverine reach. For temperature discussion see Estuary, below.

Estuary

Temperatures within the action area have generally been affected by the following Columbia River Basin-wide changes:

- Slowed river flow (both above upstream reservoirs and seasonally downstream as a result of reduced freshet flow volumes)
- Reduced riparian canopies over streamside vegetation
- Agricultural runoff
- Industrial discharges
- Climate variations such as El Nino

These changes have combined to create river temperatures that will stress fish.

Because of flow regulation within the Columbia River Basin, it is likely that the seasonal variability for salinity intrusion is reduced from historical levels (CREDDP, 1984; Thomas, 1983). Accordingly, it is likely that salinity extremes within the estuary are not as great as they were during historical extreme summer low flow and tidal conditions. For additional discussions of salinity, see Sections 2.2.1.5, 2.3.1.5, and 6.1.5.

River Mouth

See Estuary, above.

2.3.6.6 Turbidity

Turbidity levels within the action area are still influenced by the river's hydrograph rising during spring freshets; however, because dams upstream of the lower river act as sediment traps and because variability of the hydrograph has been reduced by flow regulation, interior basin spring freshets now cause only moderate increases in turbidity levels (Corps, 1999a). Theoretically, lower turbidity levels might affect survival of salmonids by increasing predation, though there is no documentation of this happening.

Riverine Reach

Turbidity levels were likely higher prior to increased development in the Columbia River Basin. High turbidity levels arise from high-suspended sediment levels. However, hydroelectric dam construction has created sediment traps. Based on observed concentrations and appropriate flow-duration curves, the Corps estimated that the average annual suspended sediment yield at Vancouver has been reduced from 12 mcy per year before any dams were built to only 2 mcy per year under today's conditions (Corps, 1999a).

Estuary

Turbidity generated by waves and current actions in the shallow flats and channels in the estuary has probably not changed from historical levels, but turbidity caused by upstream events, as noted above, would vary seasonally.

River Mouth

Because extreme seasonal flows have been reduced, there is less likelihood of high seasonal flows causing plumes with high turbidity.

2.3.6.7 Predation

Salmonids have adapted to predation pressures in part by maintaining high reproductive rates and developing variable life-history strategies for different populations that result in less concentrated migratory movements for salmonids as a whole throughout the year. Salmonids are currently preyed on by piscivorous mammals, birds, and fish in the near ocean and in the lower Columbia River estuary and freshwater areas.

Riverine Reach

See Estuary, below.

Estuary

Predation on juvenile and adult salmonids has received recent attention as increased concentrations of terns and cormorants have settled in the estuary from other locations as the birds became aware of available habitat and food sources. The number of nesting pairs increased from a few hundred pairs in 1984 to an estimated 1,200 to 2,400 cormorants and 14,000 to 16,000 Caspian terns in 1997 (Collis, et al., 2001). These numbers are much larger than those found in the historical estuary. In addition, predation by mammals such as seals and sea lions has become a concern for recreational and commercial fishermen, who regard them as competition for a scarce resource.

While estimates have ranged widely, recent analysis of passive integrated transponder tags recovered from colonies have shown that approximately 17 percent of all salmon tagged in 1998 were consumed by the cormorants and terns on Rice Island. The study also indicated that tern predation in the estuary may focus primarily on hatchery fish because they tend to reside near the surface where tern foraging occurs (Collis, et al., 2001).

Pacific harbor seals are present year-round in Washington and Oregon. Harbor seal populations on the West Coast have been increasing at a rate of about 5 to 7 percent annually since the mid-1970s. The estimated seal population from 1993 to 1995 was 34,134 in Washington and 9,251 in Oregon. Pacific harbor seals are opportunistic feeders, preying on a wide variety of benthic and epibenthic fish and cephalopods. Their diet also varies regionally, seasonally, and annually.

From October to April, California sea lions are also found in the Columbia River from Astoria to Bonneville Dam. They congregate in the river at Astoria at the east mooring basin and near fish processing plants, near the mouths of the Cowlitz and Lewis Rivers, and in the Multnomah Channel at the mouth of the Willamette River.

Although the impact of marine mammals on salmonid populations is uncertain, the presence of California sea lions and Pacific harbor seals in rivers and estuaries is a concern because pinniped predation can have a greater effect on salmonid runs that are already decreased.

Humans are also predators on salmonids in the action area. Tribal, commercial, and recreational fisheries harvest adult salmonids based on allocations set by federal, state, and tribal harvest management bodies. It is widely accepted that overharvest of salmonids occurred in the late 19th and throughout the 20th centuries. Harvest rates have been reduced over the last few decades, but the effect of such harvest on salmonid populations remains controversial.

River Mouth

See Estuary, above.

2.3.6.8 Entrainment

Entrainment refers to the process that increases mortality when fish are trapped by the force of suction in hopper or pipeline dredges. A number of entrainment studies have been performed to assess the potential for entrainment of salmonids. The consensus of these studies is essentially that dredging occurs below the depth where salmonids migrate and in different locations (Buell, 1992; Larson and Moehl, 1990; McGraw and Armstrong, 1990; R2 Resource Consultants, 1999). Salmonids typically migrate in the upper 15 feet of the water column and juveniles, in particular, tend to stay in the channel margins or shallow, shoreline areas.

Riverine Reach

See above.

Estuary

See above.

River Mouth

See above.

3 PROPOSED ACTION

The Corps proposes to deepen the authorized federal navigation channel in the Columbia River from RM 3.0 to RM 106.5 and to implement the ecosystem restoration features identified in Section 1. The nonfederal sponsors for the proposed action are the Ports of Portland and St. Helens in Oregon and the Ports of Longview, Kalama, Woodland, and Vancouver in Washington. The proposed action will deepen the existing 40-foot-deep channel to the newly authorized depth of 43 feet and maintain the existing channel alignment.

Contractors will be selected by the Corps to perform the channel improvements work. Once the channel improvements are made, the Corps will maintain the 43-foot Columbia River channel as they have the current 40-foot channel. To ensure a passable channel at all times, the Corps will continue to practice the strategy for advanced maintenance with an over-dredge of up to 5 feet in specific areas. The width of the navigation channel will be 600 feet with additional width in the turns, which is the same as the existing channel. In areas where there is a potential for high recurrence of shoaling, overwidth dredging of up to 100 feet is routinely performed. As noted previously, the Project will not require dredging the entire stretch of the navigation channel from Portland to the river mouth because significant stretches are already at or deeper than 43 feet. Specific dredging locations are discussed further in Section 3.2.

Both construction and maintenance of the 43-foot channel will be conducted using a combination of dredging methods, primarily hopper and pipeline dredges. Depending on shoaling, primary depths for dredging in the navigation channel, the turning basins, and berths associated with the Project, will be between approximately 40 and 48 feet. Construction of the proposed 43-foot channel is anticipated to require removing approximately 19 mcy of dredged material, as well as 76,000 cubic yards of basalt rock and 240,000 cubic yards of cemented sand, gravel, and boulders. To complete the construction dredging for the 43-foot channel expeditiously and economically, the Corps will construct the project continuously over a 2-year period. Once the improvements are completed, the channel will require annual maintenance dredging. Over the first 20 years, annual maintenance dredging is expected to decline from around 8 mcy to about 3 mcy of sand as the new channel reaches equilibrium. Annual maintenance will then continue at an average of about 3 mcy of sand per year for the remaining 30-year life of the project. Rock, boulders, and gravel are generally not expected to be encountered or removed during maintenance operations.

Environmental mitigation features have been proposed to offset wetland and riparian losses resulting from upland disposal. These features will be developed on a total of 740 acres of land located at the Martin Island (RM 80), Woodland Bottoms (RM 81), and Webb (RM 47) mitigation sites. The Woodland Bottoms and Webb mitigation sites are located behind flood control dikes and are not connected to the Columbia River except through pump stations and tidegates. The actions to implement those features will occur behind existing dikes that have created a barrier between the sites and the listed species and their habitat. Accordingly, these actions will not affect the indicators or pathways in the conceptual model and are not anticipated to adversely modify critical habitat.

Maintenance dredging in the existing 40-foot channel has been unrestricted by in-water work periods because the dredging is done at depths and in locations where salmonids are not generally present. Maintenance dredging on the Columbia River normally occurs annually from May to October. Pile dikes are used on both shorelines to protect disposal sites and reduce maintenance dredging needs for the 40-foot channel. Pile dikes will be maintained throughout the life of the 43-foot channel. Pile dike maintenance methods that will be used for the 43-foot channel are the same as those described in the 1996 Corps BA for maintenance of selected pile dike fields. Maintenance includes periodically replacing pilings and spreader bars that have worn out or broken.

There are 12 side channels below Bonneville Dam that are also maintained (at varying frequencies) by the Corps. No changes to these side channels are proposed as part of this consultation. Side channels are located at Baker Bay West Channel (40,000 to 50,000 cubic yards every 3 to 4 years) at RM 2.5; Chinook Channel (150,000 to 200,000 cubic yards every 1 to 2 years) at RM 5; Hammond Boat Basin (infrequently) at RM 7; Skipanon Channel (20,000 to 50,000 cubic yards every 1 to 3 years) at RM 10; Tongue Point (not maintained) at RM 17; Skamokawa (infrequently) at RM 33.6; Elochoman (infrequently) at RM 37; Westport Slough (infrequently) at RM 43; Cowlitz River Old Mouth (10,000 to 20,000 cubic yards a year) at RM 67; St. Helens Cross Channel (infrequently) at RM 87; Oregon Slough (50,000 cubic yards every 3 to 5 years) at RM 102; and Government Island (infrequently) at RM 116 (Corps, 1999a).

Methods to be used for the dredging and disposal associated with the proposed Project and maintenance of the 43-foot channel are described in this section. Channel construction and maintenance will encompass a variety of dredging and dredged material disposal activities, as well as associated conservation measures. The description includes impact minimization and best management practices (BMPs) associated with each of the anticipated activities. Additional proposed conservation measures not associated with BMPs for the respective dredging/disposal activities are described in Section 8.

Typical locations for dredging or disposal activities, both construction and maintenance, are also discussed in this section. For those disposal activities that will occur in a known location (e.g., upland disposal), specific information about the location is provided.

As part of the authorized Project, ecosystem restoration features will include the use of a combined pump/gravity water supply for restoring wetland and riparian habitat at Shillapoo Lake (RM 91). Tidegate retrofits with fish slides for salmonid passage will be installed at selected locations along the lower Columbia River. Connecting channels will be constructed at the upstream end of Walker-Lord and Hump-Fisher Islands to improve fish access to embayments and rearing habitat for juvenile salmonids.

As a result of the informal consultation, additional ecosystem restoration features have been included. These features will be constructed using several different means. Lois Island embayment and Miller-Pillar intertidal and/or subtidal habitat restoration efforts will be constructed via placement of dredged material to attain target depths at each location. Miller-Pillar will also require construction of a pile dike field (five pile dikes) to hold material in place. Bachelor Slough restoration will entail deepening an existing side channel via dredging and disposal of material either upland or in or adjacent to the navigation channel. Upland disposal of Bachelor Slough sediments will allow for the development of riparian forest habitat with the ESA Critical Habitat zone for Snake River salmonids. Purple loosestrife control will entail use of an integrated pest management approach, e.g., introduction of biological control agents, use of herbicides, and/or mechanical pulling of this exotic plant.

The interim restoration action at Tenasillahe Island will encompass improvements to existing tidegates and possible placement of water control structures at inlets to interior sloughs to improve fish accessibility and water circulation through the sloughs. Over the long-term, improvements at Tenasillahe

Island may entail breaching of exterior dikes to return tidal circulation to 1,778 acres. The long-term action is contingent upon delisting of Columbia white-tailed deer and Congressional authorization to change the purpose and objectives of these refuge lands. The last restoration proposal pertains to the translocation of Columbia white-tailed deer to Cottonwood-Howard Island near Longview, Washington. No habitat restoration is required for this latter action. Additional information regarding disposal sites is included in Appendix C.

3.1 Project Planning and Execution

There is some uncertainty associated with the final locations and extent of the shoals to be dredged because the river's bedload movement is continuous. Therefore, surveys will also be obtained for plans and specifications as well as preconstruction surveys. In addition, because contractors will be performing the channel improvements, the method of dredging in particular areas may not be known prior to the contract being awarded. So, while the Corps' plans provide guidance for timing and locations of dredging activities, the actual construction may not follow that sequence. These planning aspects of the dredging operations are discussed below.

3.1.1 Methods

3.1.1.1 Construction

Construction dredging will include a variety of techniques for removing sand and some rock from the river bottom. The amount of dredging that will be necessary in a given location varies depending on the amount and location of shoaling. Because of this variability, bathymetric (hydrographic) surveys will be conducted prior to and after each construction dredging to identify where further dredging is needed and to quantify the amount of material removed for contractor payment.

As discussed earlier, the Corps will award contracts for project activities. The contractors will choose the specific equipment to be used. Mandating specific types of dredging within the bid process has the potential to increase the expense, exacerbate already difficult timing considerations, and eliminate the benefits gained from using the expertise of the dredge operators by precluding the use of alternative actions or methods that may be more economical or efficient. Therefore, this BA addresses all types of dredging that might be used for channel improvements or maintenance.

3.1.1.2 Maintenance

Maintenance dredging will occur using the same methods currently employed to maintain the existing 40-foot channel (Corps, 1999a). Maintenance dredging for the new channel would begin when construction of the 43-foot channel is accepted by the Corps. As a result, part of the river will be maintained at 43 feet while other portions are being deepened. Annual maintenance of the channel will continue throughout the 50-year project life. It is anticipated that hopper and pipeline dredging will be the primary dredge types used to perform annual maintenance described in Sections 3.2.1 and 3.2.3.

3.1.2 Timing

The proposed construction dredging to deepen the Columbia River Channel to 43 feet would require approximately 2 years of year-round dredging. Some activity would be occurring during the entire period. Year-round dredging is proposed at depths greater than 20 feet because salmonids generally are not present in these locations.

Maintenance dredging using a pipeline would typically occur from May through October each year. Hydrographic surveys of the channel would be updated throughout the dredging season and indicate which bars need to receive maintenance dredging. A schedule for pipeline dredging is usually developed 2 weeks in advance of mobilization to each work area and is based on the results of hydrographic surveys.

Maintenance dredging using a hopper dredge begins in the spring. For maintenance of the 43-foot channel, the Corps would likely use its dredges *Yaquina* and *Essayons*. The remainder of hopper dredging in the river would occur from May 1 through October 31 using both contract and government dredges.

In-water blasting, if necessary, would occur during the recommended in-water work period of November 1 to February 28. See Table 3-1 for additional information regarding dredging timing.

Table 3-1: Dredging Timing

Construction Features	Type of Dredging	Timing
Navigation channel, including overdepth and overwidth dredging at depths greater than 20 feet	Hopper Pipeline Mechanical excavation	No timing windows No timing windows No timing windows
Turning basins at depths greater than 20 feet	Hopper Pipeline	No timing windows No timing windows
Rock removal with blasting	Mechanical excavation	November 1 to February 28
Rock removal at depths greater than 20 feet	Mechanical excavation	No timing windows
Berths	Mechanical excavation	November 1 to February 28
Ecosystem restoration features dredging at depths greater than 20 feet	Mechanical excavation Pipeline Hopper	No timing windows
Ecosystem restoration features dredging at depths less than 20 feet	Mechanical excavation Pipeline Hopper	November 1 to February 28

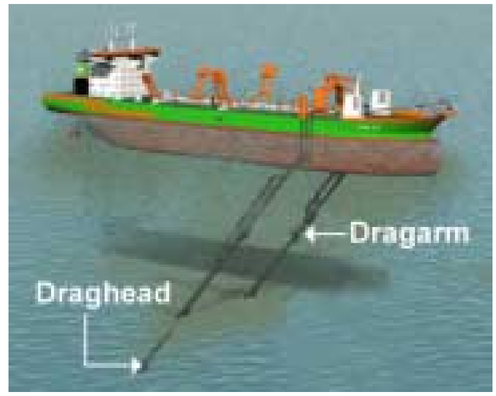
3.2 Description of Project Activities

Anticipated methods for completing the proposed project activities are described in this section. Each of the descriptions includes a general statement about the steps involved in the activity and whether they are related to construction or maintenance, followed by a brief discussion of any relevant studies performed or used by the Corps to evaluate potential adverse affects. In those instances where particular studies, general experience, or coordination with NMFS and USFWS have led to setting specific BMPs for the activities, the measures that will be used to minimize the potential impact of such activities are described. The activities and associated BMPs described in this section will be given to contractors in the bid package for all contracted dredge activities associated with project activities. Contractors will be informed that all activities must be conducted in conformance with these BMPs, and they will be mandated to provide a compliance plan.

3.2.1 Hopper Dredging

3.2.1.1 Description of Activity

Hopper dredges use a draghead at the end of dragarms located on both sides of the dredge. The dragheads are lowered to the channel bottom, and suction from the pump is used to transport material through the dragarm and into the hold of the dredge. Hopper dredges collect dredged material in the hold or "hopper" of the vessel until it is near capacity. When the hopper is filled, the dragarms are raised and the vessel moves to the disposal site. Material from hopper dredges is normally disposed of using flowlane disposal in deep areas in and adjacent to the channel. As the dredge is moving, a series of hopper doors are opened and the material is discharged at varying rates, depending on how far the hopper doors are opened. Some hopper dredges are of the "split hull" type, and some are of the "hopper door" type. In split hull hopper dredges, the hull is split open for discharging and the rate of discharge is varied by how far the hull is opened.



Suction Hopper Dredge

Hopper dredges conducting maintenance dredging currently handle about 3 mcy per year of material from the navigation channel. Hopper dredges provide flexibility for dredging operations because of their maneuverability. They are most often used on small-volume sandwave shoals in the river and on large shoals in the estuary for which pipeline dredges are less suitable. Hopper dredges are also used for maintenance dredging at the mouth of the river during the summer and fall months.

3.2.1.2 Studies/Monitoring Performed for Activities

Entrainment of organisms by hopper dredging has been evaluated at the mouth of the Columbia River and in the river itself, as well as in several coastal streams (Larson and Moehl, 1992; R2 Resources Consulting, 1990). The MCR study was begun in 1985 to assess impacts to Dungeness crab populations as a result of hopper dredging. The study obtained information on fish and found that no juvenile or adult salmonids were collected during the 4 years of the study, even though other pelagic species were collected. The study concluded that because dredging occurred below the depth where salmonids migrate, no salmon were entrained. Consequently, it is believed that few, if any, salmonids are entrained during normal maintenance dredging operations in the MCR or the Columbia River.

The only documented entrainment of salmonids occurred during a study in which the dredge draghead was operated while elevated in the water column instead of on the channel bottom and while pumping (R2 Resource Consultants, 1999). No juvenile salmonids have been entrained during normal dredging operations (Larson and Moehl, 1990).

Dredging procedures call for the draghead to be buried in the sediment of the river bed during dredging operations or raised no more than 3 feet off the river bottom when the pumps are idling to further reduce the potential for fish entrainment. Adult salmonids have sufficient swimming capacity to avoid entrainment by dredging if they are present in the vicinity of dredges and if the draghead is above the river bed when operating.

Other studies on entrainment have been conducted outside of the Columbia River. Dutta and Sookachoff (1975) and Arseneault (1982) summarized the work done by Fisheries and Marine Services of Canada on entrainment of juvenile salmonids by hydraulic dredging in the Fraser River. Their results indicated that juvenile salmonids can be entrained in large numbers when dredging is done in narrow channel areas near the shore. The Fraser River study focused on an area that was narrow and constrained, and therefore, the conclusions would not be pertinent to the Columbia River because of its large cross-sectional area. Other entrainment studies, in more open areas with the dredging taking place farther from shore, have shown less entrainment. In Grays Harbor, Washington, Bengston and Brown (1977) made some limited observations of pipeline-dredged material as it was being discharged, and Tegelberg and Arthur (1977) made observations on fish entrained by both hopper and pipeline dredges. Neither study showed any salmonids entrained. Stevens (1981) collected data in Grays Harbor on fish entrained by pipeline, hopper, and clamshell dredges, and Armstrong, et al. (1982), evaluated impacts of dredging on fish as part of a Dungeness crab study in Grays Harbor. Only a single chum salmon was collected.

In 1997 and 1998, hydro-acoustic studies were done in the lower Columbia River to determine the distribution of juvenile salmonids in the navigation channel. The results show that most yearling juvenile salmonids were located along the navigation channel margins while migrating (Carlson, 2001). Because dredging would not occur in the channel margins, these fish would not be susceptible to entrainment levels exhibited in the Fraser River studies (Dutta and Sookachoff, 1975; Arseneault, 1982).

3.2.1.3 Impact Minimization Measures Applied to Activity

Hopper and pipeline dredges generally do not produce large amounts of turbidity during dredging because of the suction action of the dredge pump and the fact that the dragarm or cutter head is buried in the sediment. In addition, entrainment is not expected to occur as dredging is done at depths of more than 40 feet and salmonids generally migrate at depths of less than 15 feet. The primary impact minimization measure anticipated for hopper dredging is to require dredges to stop pumping when raising the draghead more than 3 feet from the bottom. This is normally done by the dredge operators and has been required by NMFS since the September 1999 BO for maintenance dredging of the 40-foot channel.

3.2.2 Mechanical Dredging

Mechanical dredges remove material by scooping it up with a bucket. Mechanical dredges include clamshell, dragline, and backhoe dredges. Mechanical dredges are well suited for removing cemented sands, gravels, or well-fractured rock outcrops. Accordingly, mechanical dredging is likely to be chosen by the contractor during channel construction to remove cemented conglomerates near Longview, Washington (Slaughter’s Bar), and may also be used on the rock outcropping at Warrior Rock near St. Helens, Oregon. Mechanical dredges would only be used for maintenance dredging in discrete areas where other forms of dredging may not be effective. For example, mechanical dredges are often used under bridges and in other tight areas, like the berthing areas, to remove small amounts of material.

3.2.2.1 Description of Activity

Mechanical dredging is performed using a bucket operated from a crane or derrick that is mounted on a barge or operated from shore. Sediment from the bucket is usually placed on a barge for offloading and disposal to an upland or in-water site.

Clam Shell Dredge

Because mechanical dredges are not self-propelled, they are not typically used in high traffic areas; rather, they are used in tighter spaces such as around docks and piers. Also, because they are usually situated on a barge, clamshell dredges can be used in restricted areas and shallow areas where draft restrictions may limit other choices. A clamshell dredge will be used to deepen the berths, which are restricted areas, and remove the cemented cobbles in the Slaughter's Bar area (near the Longview bridge). Mechanical dredges equipped with special buckets are often regarded as being particularly useful in silts or contaminated materials where water entrapment may be a problem. Mechanical dredges are used for side channel projects related to the Columbia River navigation channel.

3.2.2.2 Studies/Monitoring Performed for Activities

It is generally believed that clamshell dredging causes less adverse impact than other types of dredging. Stevens (1981) collected data in Grays Harbor on entrainment by pipeline, hopper, and clamshell dredges, and also evaluated the impacts of dredging on fish as part of a Dungeness crab study in Grays Harbor. The study did not show any salmon collected. Armstong, et al. (1982), in a similar study of the impacts of dredging on Dungeness crabs in Grays Harbor, reported catching one juvenile chum salmon. Both studies were conducted during the time period of early winter through late summer.

3.2.2.3 Impact Minimization Measures Applied to Activity

It is generally believed that entrainment by clamshell dredging does not occur because juvenile and adult salmonids are able to avoid entrainment by the clamshell bucket, in part because they are alerted to danger by a pressure wave created as the bucket is dropped through the water column. Based on this, clamshell dredging has not been timing restricted, even in shallow water areas.

Mechanical dredging will be used to remove rock and cemented cobbles not associated with blasting, and could conceivably be done during the in-water work period. The amount of turbidity produced by mechanical dredging depends on the type of bucket used. An open bucket dragline can produce the most amount of turbidity. A closing bucket generally produces less turbidity than the dragline type.

3.2.3 Pipeline Dredging

3.2.3.1 Description of Activity

Pipeline dredges are used for large cutline shoals and areas with multiple sandwave shoals. A pipeline dredge uses a "cutter head" on the end of an arm that is buried about 3 to 6 feet deep in the river bottom material and swings in a 250- to 300-foot arc in front of the dredge. Dredged material is sucked up through the cutter head and the pipes, then pumped to upland disposal sites or disposed of in-water, as described below.

Upland disposal sites have been identified throughout the project area. Material dredged from the channel will be pumped to these sites by pipeline dredge. Dikes will be constructed at these sites to contain the material and water. The return water will be held in settling ponds controlled by weirs.

Pipeline Dredging

Future pipeline maintenance dredging is expected to be about 3 to 5 mcy per year. Maintenance dredging done by pipeline will use the Port of Portland's 30-inch dredge, the *Oregon*, from May through September. In a typical maintenance season, the *Oregon* will begin river dredging at shoals in the estuary and then progress upstream.

Flowlane disposal uses a "down pipe" with a diffuser plate at its end. The down pipe extends 20 feet below the water surface to avoid impacts to migrating juvenile salmonids. The diffuser and movement of the pipe help prevent mounds from forming on the river bottom.

3.2.3.2 Studies/Monitoring Performed for Activities

Buell (1992) studied entrainment of fish by pipeline dredging in the study area. Entrainment only occurred when the fish were in the immediate vicinity of the cutter head. Because the proposed pipeline dredging for the main navigation channel will occur at 40 feet and deeper, individuals of listed species are not expected to be near the cutter head. As mentioned in the section on hopper dredging, applicable entrainment studies found no salmonids entrained during dredging. In Grays Harbor, Washington, Bengston and Brown (1977) made some observations of pipeline-dredged material as it was being discharged, and Tegelberg and Authur (1977) made observations on fish entrained by both hopper and pipeline dredges. Neither study showed any salmonids entrained. Stevens (1981) collected data in Grays Harbor on fish entrained by pipeline, hopper, and clamshell dredges, and Armstrong, et al. (1982), evaluated impacts of dredging on fish as part of a Dungeness crab study in Grays Harbor.

3.2.3.3 Impact Minimization Measures Applied to Activity

Pipeline dredges generally do not produce large amounts of turbidity during dredging because of the suction action of the dredge pump and the fact that the cutter head is buried in the sediment. Impacts to salmonids, including entrainment, can be avoided by operating hopper dragheads and pipeline cutter heads only within 3 feet of the river bottom. Impact minimization practices and BMPs for dredging are listed in Table 3-2.

Table 3-2: Impact Minimization Practices and Best Management Practices for Dredging

Measure	Justification	Duration	Management Decision
Hopper Dredging			
Maintain dragheads in the substrate or no more than 3 feet above the bottom with the dredge pumps running.	This restriction minimizes or eliminates entrainment of juvenile salmon during normal dredging operations.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.
Dredging in shallow water areas (less than 20 feet) only during the recommended ESA in-water work period for the Columbia River of November 1 until February 28.	Areas less than 20 feet deep are considered salmon migratory habitat. Dredging or disposal in these areas could delay migration or reduce or eliminate food sources.	Continuous during dredging and disposal operations.	Maintain until new information becomes available that would warrant change.
Pipeline Dredging			
Maintain dragheads in the substrate or no more than 3 feet above the bottom with the dredge pumps running.	This restriction minimizes or eliminates entrainment of juvenile salmon during normal dredging operations.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.
Dredging in shallow water areas (less than 20 feet) only during the recommended ESA in-water work period for the Columbia River of November 1 until February 28.	Areas less than 20 feet deep are considered salmon migratory habitat, Dredging or disposal in these areas could delay migration or reduce or eliminate food sources.	Continuous during dredging and disposal operations.	Maintain until new information becomes available that would warrant change.
General Provisions for All Dredging			
The contractor shall not release any trash, garbage, oil, grease, chemicals, or other contaminants into the waterway.	Protection of water resources.	Life of contract or action.	If material is released, it shall be immediately removed and the area restored to a condition approximating the adjacent undisturbed area. Contaminated ground shall be excavated and removed and the area restored as directed. Any in-water release shall be immediately reported to the nearest U.S. Coast Guard Unit for appropriate response.
The contractor, where possible, will use or propose for use materials that may be considered environmentally friendly in that waste from such materials is not regulated as a hazardous waste or is not considered harmful to the environment. If hazardous wastes are generated, disposal of this material shall be done in accordance with 40 CFR parts 260-272 and 49 CFR parts 100-177.	Disposal of hazardous waste.	Life of contract or action.	If material is released, it shall be immediately removed and the area restored to a condition approximating the adjacent undisturbed area. Contaminated ground shall be excavated and removed and the area restored as directed. Any in-water release shall be immediately reported to the nearest U.S. Coast Guard Unit for appropriate response.

3.2.4 Berth Deepening at Lower Columbia River Ports

Three grain facilities and one container terminal on the Columbia River are identified in the Corps' FEIS (1999a) as benefiting from channel deepening. Vessel berths alongside two of these facilities – the Port of Kalama grain elevator operated by United Harvest and the Port of Portland's Terminal 6 – will require dredging to "achieve the benefits of any channel deepening alternative" (Corps, 1999a). One berth will be deepened at the United Harvest elevator, located just north of the City of Kalama. Three berths, totaling approximately 2,800 linear feet, will be deepened at Terminal 6, located at the confluence of the Columbia and Willamette Rivers.

Since the FEIS was completed in August 1999, U.S. Gypsum has opened a facility on the Columbia River at the Port of St. Helens. This facility will also require berth deepening to benefit from channel deepening. Section 6.9, of the FEIS (Corps, 1999a) Secondary Impacts, addresses "additional dredging requirements at port berthing areas," and specifies that the local ports would be required to obtain dredging permits for their facilities.

3.2.4.1 Studies/Monitoring Performed for Berth Deepening

For the purposes of evaluating the feasibility of the proposed Project and providing preliminary data for inclusion in the FEIS, a sediment characterization study was prepared for the berths to be deepened (Corps, 1999a, Appendix B). Volume I of the study is included in Appendix B of the FEIS (Corps, 1999a). Sediment core samples were taken at the United Harvest berth at Kalama, at the berths at Terminal 6 in Portland, and at the Longview grain wharf. Except for one sample at Terminal 6, which indicated a need for further evaluation to determine the appropriate disposal option, the study found that all sediments in the 42- to 45-foot dredging prism were determined to be suitable for unconfined in-water disposal, based on the Corps' Dredged Material Evaluation Framework. If testing prior to actual dredging reveals that the material is not suitable for in-water disposal, material dredged from these berths will be disposed of in such a manner that unacceptable environmental impacts will be avoided (Corps, 1999a). The same is true for the U.S. Gypsum site if that berth is deepened.

3.2.5 Flowlane Disposal

3.2.5.1 Description of Activity

Normally, flowlane or in-water disposal distributes dredged material in sites within or adjacent to the navigation channel and downstream of the dredging area at depths greater than the channel. This is done to minimize the potential for material settling back into the channel and causing additional shoaling problems. Approximately 3 mcy of construction material will be disposed of in the flowlane, with 2.5 mcy between RM 27 and 42. Flowlane disposal for maintenance is approximately 24 mcy over 20 years. The average annual quantity of maintenance material for flowlane disposal is expected to be 2 to 4 mcy. This type of dredged material disposal is to be done throughout the Columbia River navigation channel where depths range from 35 to 65 feet, but are typically greater than 50 feet. Disposal sites are not specifically designated because they vary according to the condition of the channel and the techniques used by the contractor selected to perform the work. Flowlane disposal is dispersed along the channel to avoid creating mounds.

3.2.5.2 Studies/Monitoring Performed for Activities

In a 1997 study for the Corps by McCabe, NMFS examined fish, particularly white sturgeon, in bottom habitats in six flowlane disposal areas in the Columbia River between RM 24 and 81. The study concluded that larval and young-of-the-year white sturgeon would probably be most affected by flowlane disposal, with the impact depending on the amount of material deposited on the fish. The study concluded that laboratory research is needed to determine the mechanical impacts of flowlane disposal on white sturgeon. The study identified no impacts to salmonids.

Benthic invertebrates, which are a major food source for salmonids, are most abundant at depths of less than 20 feet. Benthic sampling in the flowlane has found low benthic invertebrate abundance (McCabe, 1997).

3.2.5.3 Impact Minimization Measures Applied to Activity

As noted in the preceding discussion, flowlane disposal is done throughout the Columbia River navigation channel. For the Project, flowlane disposal would be in depths generally ranging from 50 to 65 feet. The benthic invertebrates that provide a major food source for some fish are found at depths of less than 20 feet. Restricting the disposal of dredged materials to depths greater than 20 feet will minimize potential impacts from this activity. To avoid mounding during hopper-dredge disposal, material will be released while the dredge is in motion to disperse material over the flowlane disposal area. During disposal or placement of dredged material by pipeline dredge, the diffuser on the down pipe will be moved continually to prevent mounding on the river bottom.

3.2.6 Upland Disposal

3.2.6.1 Description of Activity

Upland disposal will be the most frequently used method for disposing of sediment associated with channel deepening construction. Disposal of sediments on designated upland sites will be done primarily with pipeline dredges. Material could also be loaded onto barges with mechanical dredges and then off-loaded at a temporary dock near the disposal site. The material would be taken to an upland site by heavy equipment. Pipeline dredges pump a water and sand slurry through pipes directly from the dredge's location on the river to the upland disposal site. Both the pipeline landfall and the offloading facility for the barge will be temporary and will only be in place until the disposal site is full or the dredging is completed. The off-loading area will be restored to predisposal conditions after use.

Most upland sites used for both channel construction and maintenance are designed as holding ponds, with earthen dikes to contain the dredged material and hold the return water while allowing sand and suspended sediment to settle (Figure 3-1). Weirs are used to regulate the return of water to the river. Once the pipeline dredge deposits the material and the water is drained, the sand is "drifted" or spread evenly around the holding area. Water returned to the river through weirs is subject to applicable water quality standards, after dilution, at an appropriate point of compliance.

Figure 3-1: Upland Disposal Site Typical Plan View

Of the 29 upland disposal sites proposed for channel construction, only five will be new sites that have not been previously used for maintenance dredging disposal: Mount Solo, Puget Island, Gateway, Fazio Adjacent, and Railroad Corridor. Because of the previous use at most of the upland disposal sites, site capacities will vary. Some sites will be used only for channel construction, some for both construction and maintenance of the new channel, and some just for maintenance. The useful life and capacity of these diked disposal sites is normally extended by building a series of "lifts," which are placed on top of the deposited sand after a specified height is reached (Figure 3-2). These upland disposal sites may accommodate one to three lifts, depending on the characteristics of the site. Section 3.3 of this BA identifies those sites and activities that result from deepening the channel and subsequent maintenance.

3.2.6.2 Studies/Monitoring Performed for Activities

A number of studies have been conducted to evaluate the suitability of potential upland disposal sites. Environmental site assessments (Phase I) have been performed for each of the potential upland disposal sites, and these are available as separate documents. Interagency Habitat Evaluation Procedure (HEP) analyses have been prepared for each site, the results of which are summarized in the (Corps, 1999a). In Oregon, follow-up habitat evaluations are being conducted in coordination with the Oregon Division of State Lands, and additional wetland evaluations have been conducted at specific disposal site locations in both states. To date, upland disposal along the Columbia River channel is not known to have had any adverse impacts on listed fish species or proposed critical habitat.

3.2.6.3 Impact Minimization Measures Applied to Activity

As indicated above, upland disposal along the Columbia River channel is not known to have had any adverse impacts on listed fish species or proposed critical habitat to date; however, several measures will minimize the potential for impact from this activity. Minimum buffer widths between disposal sites and the river are planned to protect riparian corridors where applicable (see Figure 3-1). The riparian edge along the shoreline, if present, will be avoided whenever possible, as is done with current maintenance dredging. A survey of riparian areas was made by NMFS and the Corps, and areas of significance were delineated so that they could be avoided. Proposed sites have either been located to avoid wetland impacts or, if impacted, wetlands are to be mitigated at a ratio of 1:5. In addition, many sites will be replanted and regraded after they are no longer used for dredged material disposal. Sites that have been used for past dredged material disposal were selected first. Sites from which dredged materials could be used beneficially or sold were also selected in preference to other locations.

Figure 3-2: Typical Dike Cross Section for a Hypothetical Upland Disposal Site

3.2.7 Shoreline Disposal

3.2.7.1 Description of Activity

Throughout the year, the combination of river flows, wind waves, ship wakes, and tidal effects erode sand from river beaches. In the past, many of those beach areas have been replaced with dredged material through shoreline disposal. Where shoreline disposal is used to replace the eroded areas with dredged sand, it is called "beach nourishment." Shoreline disposal is done primarily with pipeline dredges. Material dredged from the main navigation channel is pumped to a shallow water and beach area. The dredge first pumps a landing on the beach to establish a point from which further material placement occurs. Dredged material is pumped as a sand and water slurry (about 20 percent sand). As it exits the shore pipe, the sand quickly settles out on the beach while the water returns to the river. Once sand begins to accumulate, it is spread by bulldozer to match the elevation of the existing beach. A typical shoreline disposal operation occurs only once at any location during the dredging season. It takes from 5 to 15 days to fill a site, depending on the size of the site and the amount of material to be dredged. The width of the beach that is created is approximately 100 to 150 feet riverward. The process continues by adding length to the shore pipe and proceeding longitudinally along the beach. After disposal the beach is groomed to a minimum steepness of 10 to 15 percent to prevent the possibility of creating areas where fish could be stranded by wave action.

Shoreline disposal of dredged material during channel construction is anticipated to occur at Sand Island (O-82.6).[15] Sand Island, Skamokawa (W-28), and Miller Sands (O-23.5) will be used periodically for maintenance disposal.

3.2.7.2 Studies/Monitoring Performed for Activities

NMFS, under contract to the Corps, examined the quality and quantity of benthic invertebrate communities at 10 historical beach nourishment areas in the lower Columbia River (McCabe and Hinton, 1996). The goal of the study was to determine whether NMFS would allow any of these sites to be used in the future. The 10 locations were sampled quarterly between July 1994 and April 1995. The report determined that the sites were fairly productive for benthic invertebrates, including *Corophium salmonis*, an important food source for juvenile salmonids. The study also suggested that productivity levels depend on the erosive nature of the site. McCabe and Hinton found that the two highly erosive sites were significantly less productive than the other sites studied.

3.2.7.3 Impact Minimization Measures Applied to Activity

Based on the results of the 1996 McCabe and Hinton study, only sites determined to be highly erosive have been selected for use as beach nourishment areas. In addition, all grading at the sites must result in slopes from 10 to 15 percent to minimize the potential for stranding by wave and wake action. Impact minimization measures, also referred to as BMPs, for disposal are listed in Table 3-3.

[15] Onshore locations are designated by a state code plus a river mile. For example O-82.6 is on the Oregon side of the Columbia River at RM 82.6; W-82.6 would be the corresponding point on the Washington side.

Table 3-3: Best Management Practices for Disposal

Measure	Justification	Duration	Management Decision
Flowlane Disposal			
Dispose of material in a manner that prevents mounding of the disposal material.	Spreading the material out will reduce the depth of the material on the bottom, which will reduce the impacts to fish and invertebrate populations.	Life of contract or action.	Maintain until new information becomes available that would warrant change.
Maintain discharge pipe of pipeline dredge at or below 20 feet of water depth during disposal.	This measure reduces the impact of disposal and increased suspended sediment and turbidity on migration juvenile salmonids, since they are believed to migrate principally in the upper 20 feet of the water column.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.
Upland Disposal			
Berm upland disposal sites to maximize the settling of fines in the runoff water.	This action reduces the potential for increasing suspended sediments and turbidity in the runoff water.	Continuous during disposal operations.	Maintain until new information becomes available that would warrant change.
Maintain 300-foot habitat buffer.	This action maintains important habitat functions.	Life of contract or action.	Maintain until new information becomes available that would warrant a change.
Shoreline Disposal			
Dispose of material in shallow water areas (less than 20 feet) only during the recommended ESA in-water work period for the Columbia River of November 1 until February 28.	Areas less than 20 feet deep are considered salmon migratory habitat. Dredging or disposal in these areas could delay migration or reduce or eliminate food sources.	Continuous during dredging and disposal operations.	Maintain until new information becomes available that would warrant change.
Grade disposal site to a slope of 10 to 15 percent, with no swales, to reduce the possibility of stranding of juvenile salmonids.	Ungraded slopes can provide conditions on the beach that will create small pools or flat slopes that can strand juveniles washed up by wave action.	Continuous during dredging and disposal operations.	Maintain until new information becomes available that would warrant change.
Ocean Disposal			
Disposal of material in accordance with the site management and monitoring plan, which calls for a point dump placement of any construction material. The plan is to place any construction material in the southwest corner of the deep water site.	This action minimizes conflicts with users and impacts to ocean resources.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.
General Provisions for All Disposal			
Disposal of hazardous waste.	The contractor, where possible, will use or propose for use materials that may be considered environmentally friendly in that waste from such materials is not regulated as a hazardous waste or is not considered harmful to the environment. If hazardous wastes are generated, disposal of this material shall be done in accordance with 40 CFR parts 260-272 and 49 CFR parts 100-177.	Life of contract or action.	If material is released, it shall be immediately removed and the area restored to a condition approximating the adjacent undisturbed area. Contaminated ground shall be excavated and removed and the area restored as directed. Any in-water discharge shall be immediately reported to the nearest U.S. Coast Guard Unit for appropriate response.

3.2.8 Ocean Disposal

The FEIS (Corps 199a) stated that during construction of the 43-foot alternative, about 7 mcy (5 mcy new work plus 2 mcy for the 40-foot channel maintenance) of material would be disposed of in ocean disposal sites. An additional 9 mcy derived from channel maintenance would be placed in the ocean sites during the 20-year project period. The quantity is expected to be reduced because of new restoration actions described in this BA.

A new deep water site is located about 4.5 miles west of RM 1; its outer boundary is approximately 7 miles west of RM 1 (Figure 3-3). Water depths vary from 200 to 300 feet deep. Overall site dimensions are 17,000 feet by 23,000 feet and consist of an inner rectangle measuring 11,000 feet by 17,000 feet, surrounded on all sides by a 3,000-foot buffer. The site encompasses 8,980 acres. Disposal of dredged material would only be allowed within the inner dumping or target zone. The inner placement area of the site has a total area of 4,293 acres and a static disposal capacity of 225 mcy. Material placed at this site is expected to create a mound approximately 40 feet high within the target zone over the estimated 50-year life of the site. No direct disposal of dredged material would be allowed anywhere in the buffer; however, dredged material sloughing off the developing mound may extend into the buffer zone.

3.2.8.1 Studies Monitoring/Performed for Ocean Disposal

A joint Environmental Protection Agency (EPA) and Corps general approach to site designation for ocean dredged material disposal sites (ODMDS) was published in 1984. This guidance was developed to provide procedures for the identification, evaluation, and selection for final designation of ODMDS. A management plan, which includes a monitoring component, is mandatory.

For the ocean disposal site, EPA and the Corps followed these procedures and conducted and reviewed studies that include information in the areas of living resources, physical processes, geological resources, sediment quality, water quality, cultural resources, and recreational resources. In total, 143 separate studies are noted in Appendix H of the FEIS (Corps, 1999a). Two ocean dredged material disposal sites, needed for long-term use by the MCR and inner channel are proposed for designation by EPA. Additional studies will be conducted at the deeper site, particularly with regard to biological baseline studies. Monitoring will be conducted annually in accordance with the management/monitoring plan.

Figure 3-3: Ocean Disposal Area

3.2.8.2 Impact Minimization Measures Applied to Activity

An adaptive management approach is applied to monitoring and use of the ocean disposal site (the deep water site). This approach involves coordinating site management plans with the state resource agencies to help minimize impacts to marine resources. EPA and the Corps will be conducting pre- and post-construction assessment studies for the deep water site. These assessments will include special studies in addition to routine bathymetric surveys. EPA and the Corps acknowledge the need for biological data. The scope for the special studies will be developed and scoped during the preconstruction engineering and design phase. The special studies may include the following:

- Side scan sonar
- Sediment characterization
- Crab distribution and abundance studies
- Benthic sampling

3.2.8.3 Baseline Studies

The Marine Protection Research and Sanctuary Act Section 102(c)(3)(A) requires that the management plan include a baseline of conditions at the site.

There is only limited information on biological resources of the deep water site. Additional baseline studies will be needed to characterize this site. The scope of these baseline studies will be decided after input is received from the Corp's Ocean Disposal Taskforce.

3.2.9 Drilling and Blasting

3.2.9.1 Description of Activity

Removal of approximately 75,000 cubic yards of rock would be required at Warrior Rock (RM 87.3). This may require in-water drilling and blasting to loosen and fracture rock (basalt) so that it can be removed for construction of the 43-foot channel. Mechanical methods such as a large clamshell dredge would be tried first to see if the rock could be removed. If not, a blasting plan would be developed with state and federal agencies, indicating the location and pattern of holes to be dug for placement of the charges needed to fragment the rock. The holes would be drilled and charges set to create an implosion, rather than an explosion, for minimum impact on fish. Following the blasting of the rock, a clamshell dredge would likely be used to remove the loosened material. Such blasting would be limited to the "in-water work window" period between November through February.

Drilling and blasting will not be required for maintenance dredging in the 43-foot channel.

3.2.9.2 Studies/Monitoring Performed for Activities

Studies indicating the potential effects of blasting on Columbia River aquatic life are not available. The effects of blasting on benthic invertebrates are unknown because little work has been done regarding pressure impacts to these species. Benthic communities in the immediate vicinity of the blast (specifically those sediments or rocks removed) are likely to be destroyed. Following material excavation, however, it is expected that these communities would quickly recover to pre-blast levels.

3.2.9.3 Impact Minimization Measures Applied to Activity

Mechanical excavation of rock areas is not expected to have any more impact than the other dredging operations discussed previously. In the event that rock must be blasted, several measures would be taken to minimize impacts. The principal impact of blasting is the injury caused to fish by the pressure wave produced by the explosive. If the over-pressure (the pressure over the blast zone) exceeds several hundred pounds per square inch (psi), fish may be injured. NMFS has requested that over-pressures be kept at 10 psi or lower to prevent injury to listed salmonids. This level would also protect other species of resident and anadromous fish. The contractor would drill and fill with explosive in as many holes as possible during one 12-hour shift. Each hole would contain 100 pounds or less of explosives. Each charge would be detonated on a delay so that only 100 pounds of explosive would be detonated at one time, with the blast occurring as an implosion rather than an explosion, to reduce its area of impact. In this way over-pressures will be kept to 10 psi or less at distances of 30 to 50 feet from the blast point. Over-pressures would also be monitored to ensure that they remained below 10 psi. In addition, measures would be used to scare fish away prior to the blast (Cimmino, pers. comm., 1997).

Incorporating these measures should minimize impacts to fish during blasting to the maximum extent possible. A detailed fish-monitoring and protection plan will be developed and coordinated with the state resource agencies prior to blasting.

3.2.10 Conservation Measures

A conservation measure is any impact minimization measure, mitigation activity, or BMP that the Corps may employ to offset identified or potential adverse effects from dredging and disposal activities. BMPs and impact minimization measures associated with a specific proposed activity have been discussed within the particular subsection describing that activity. Details regarding other general impact avoidance, mitigation, or monitoring measures are discussed in Section 8 of this document.

3.3 Activities Proposed within Respective Reaches

This section presents the locations where dredging, disposal mitigation, and ecosystem restoration activities will occur during channel construction and operations and maintenance. Following is a brief description of each of the project reaches in which dredging and disposal activities will occur and identification of some of the major features within each reach, together with graphics indicating the known disposal sites.

3.3.1 River Reach A – River Mile 106.5 to 146

River Reach A is included in this BA because project activities downstream may cause incidental impacts in this reach by decreasing river water surface elevations slightly. No direct project activities will occur in this reach.

3.3.2 River Reach 1 – River Mile 98 to 106.5

The upper extent of the proposed project activity is located at RM 106.5 at the Interstate 5 Highway Bridge. The reach continues downstream to RM 98, which is located downstream of the confluence of the Willamette and Columbia Rivers adjacent to Sauvie Island. The Ports of Vancouver and Portland are in this reach. Areas where Project actions will take place within River Reach 1 include dredging areas for the navigation channel, as well as upland and flowlane dredged material disposal locations (Figure 3-4).

The Corps' dredging areas within Reach 1 are:

- Vancouver Turning Basin
- Lower Vancouver Bar
- Morgan Bar

Proposed upland disposal sites within Reach 1 are:

- West Hayden Island, O-105.0
- Gateway 3, W-101.0

Berths to be deepened in Reach 1 are:

- Terminal 6
- United Grain in Vancouver

Other actions in Reach 1 include:

- Deepening the Turning Basin at RM 105.5
- Shillapoo Lake Restoration

3.3.3 River Reach 2 – River Mile 84 to 98

The upper portion of River Reach 2 is located at RM 98, which is near the midpoint of Sauvie Island. The reach runs approximately 14 miles to RM 84, which is located just downstream from St. Helens, Oregon. The Ports of St. Helens and Woodland are in this reach. Action areas within River Reach 2 include dredging areas for the navigation channel, as well as upland and flowlane dredged material disposal locations (Figure 3-4). As noted in the discussion on dredging activities, Warrior Rock near St. Helens is a location where a clamshell dredge might be the appropriate tool. In the case of the Warrior Rock area, the presence of basalt may require the use of blasting to loosen the material for subsequent dredging. Shoreline disposal will also occur at Sand Island in St. Helens County Park. Dredged materials will be used to replace sand lost to erosion in this recreational area. This is called "beach nourishment."

The Corps' dredging areas within Reach 2 are:

- Willow Bar
- Henrici Bar
- Warrior Rock Bar (some blasting potential in this area)
- St. Helens Bar

Proposed upland disposal sites within Reach 2 are:

- Fazio Sand and Gravel (Fazio A), W-97.1
- Fazio Adjacent (Fazio B), W-96.9
- Lonestar, O-91.5
- Railroad Corridor, O-87.8
- Austin Point, W-86.5

Proposed shoreline disposal will occur at:

- Sand Island, O-86.2

Other actions in Reach 2 include:

- Bachelor Slough Restoration

Figure 3-4: Reach 1 and 2 Disposal Sites and Dredge Areas RM 84-106.5

3.3.4 River Reach 3 – River Mile 70 to 84

The upper portion of River Reach 3 is located around RM 84, just downstream from St. Helens, Oregon. The reach runs approximately 14 miles to RM 70, which is between Cottonwood and Howard Islands. The Port of Kalama is in this reach. Action areas within River Reach 3 include dredging for areas of the navigation channel, as well as upland and flowlane dredged material disposal locations (Figure 3-5).

The Corps' dredging areas within Reach 3 are:

- Upper Martin Island Bar
- Lower Martin Island Bar
- Kalama Ranges
- Upper Dobelbower Bar

Proposed upland disposal sites within Reach 3 are:

- Martin Bar, W-82.0
- Reichold, O-82.6
- Lower Deer Island, O-77.0
- Sandy Island, O-75.8
- Northport, W-71.9
- Cottonwood Island, W-70.1

Proposed shoreline disposal will occur at:

- Martin Island Lagoon

Berths to be deepened in Reach 3 are:

- Peavy Grain in Kalama
- Harvest States in Kalama

Other actions in Reach 3 include:

- Deepening the Turning Basin at 73.5
- Burris Creek Tidegate
- Deer Island Tidegate
- Howard/Cottonwood Translocation of Columbia White-tailed Deer
- Flowlane Disposal

3.3.5 River Reach 4 – River Mile 56 to 70

The upper portion of River Reach 4 is located near RM 70, which is between Cottonwood and Howard Islands. The reach runs approximately 14 miles to RM 56, which is located at Crims Island. The Port of Longview is in this reach. Slaughters Bar, a well-known feature in this reach, is a site where the use of a mechanical dredge might be required to remove cemented sands and gravels in the area. Action areas within River Reach 4 include dredging areas for the navigation channel, as well as upland and flowlane dredged material disposal sites (Figure 3-6).

The Corps' dredging areas within Reach 4 are:

- Lower Dobelbower Bar
- Slaughters Bar
- Walker Island Reach
- Stella-Fisher Bar

Figure 3-5: Reach 3 Disposal Sites and Dredge Areas RM 70-84

Figure 3-6: Reach 4 Disposal Sites and Dredge Areas RM 56-70

Proposed upland disposal sites within Reach 4 are:

- Howard Island, W-68.7
- International Paper Rehandle, W-67.5
- Rainier Beach, O-67.0
- Rainier Industrial, O-64.8 (not constructed until 2003)
- Lord Island, O-63.5
- Reynolds Aluminum, W-63.5
- Mount Solo, W-62.0
- Hump Island, W-59.7
- Crims Island, O-57.0

Berths to be deepened in Reach 4 are:

- U.S. Gypsum near Rainier

Other actions in Reach 4 include:

- Hump Fisher Restoration
- Ford Walker Restoration
- Flowlane Disposal

3.3.6 River Reach 5 – River Mile 40 to 56

The upper portion of River Reach 5 is located at Crims Island around RM 56. The reach runs approximately 15 miles to RM 41. The navigation channel runs north of the island. Action areas within River Reach 5 include dredging areas for the navigation channel, as well as upland and flowlane dredged material disposal sites (Figure 3-7).

The Corps dredging areas within Reach 5 are:

- Gull Island Bar
- Eureka Bar
- Westport Bar
- Wauna and Driscoll Ranges

Proposed upland disposal sites within Reach 5 are:

- Port Westward, O-54.0
- Brown Island, W-46.3
- Puget Island, W-44.0
- James River, O-42.9

Other actions in Reach 5 include:

- Flowlane Disposal

3.3.7 River Reach 6 – River Mile 29 to 40

The upper portion of River Reach 6 is located near RM 40, which runs through the lower end of Puget Island in the vicinity of Cathlamet. The reach runs approximately 11 miles to RM 29, where the river begins to broaden considerably. Action areas within River Reach 6 include some dredging areas for the navigation channel, as well as upland and flowlane dredged material disposal sites (Figure 3-8).

The Corps' dredging areas within Reach 6 are:

- Puget Island Bar
- Skamokawa Bar
- Brookfield-Welch Island Bar

Proposed upland disposal sites within Reach 6 are:

- Tenasillahe Island, O-38.3 (channel maintenance)
- Welch Island, O-34.0 (channel maintenance)
- Skamokawa, W-33.4 (channel maintenance)

Other actions in Reach 6 include:

- Tenasillahe Island Restoration
- Flowlane Disposal

Figure 3-7: Reach 5 Disposal Sites and Dredge Areas RM 40-56

Figure 3-8: Reach 6 Disposal Sites and Dredge Areas RM 29-40

3.3.8 River Reach 7 – River Mile 3 to 29

River Reach 7 encompasses the Columbia River estuary, which is the extreme lower end of the watershed. It extends from RM 29 to the river mouth at RM 3. The estuary, which ranges from 4 to 5 miles in width, contains two main channels. The south channel is an extension of the main river channel upstream of the estuary and carries most of the upland river discharge. The navigation channel follows the south channel through the estuary. The north channel extends upstream to about RM 20. Wide and shallow intertidal and subtidal flats separate these two deep channels. A few of the well-known features within this reach include Miller Sands Channel, Flavel Bar, and Tongue Point Crossing. Action areas within River Reach 7 will be some estuarine dredging areas for the navigation channel and upland, shoreline, and flowlane dredged material disposal sites (Figure 3-9).

The Corps' dredging areas within Reach 7 are:

- Pillar Rock Ranges
- Miller Sands Channel
- Tongue Point Crossing
- Upper Sands
- Flavel Bar
- Upper Desdemona Shoal
- Lower Desdemona Shoal

Proposed upland disposal sites within Reach 7 are:

- Pillar Rock Island, O-27.2 (channel maintenance)
- Miller Sands, O-23.5 (channel maintenance)
- Rice Island, W-21.0 (channel maintenance)

Other actions in Reach 6 include:

- Turning Basin at RM 13
- Miller-Pillar Restoration
- Lois Island Restoration
- Purple Loosestrife Control
- Flowlane Disposal

3.3.9 River Mouth – Reach B (RM 3 to the Outer Edge of the Deep Water Site)

River Reach B of the project extends into the Pacific Ocean to the western boundary of the deep water site. Proposed project activities within this reach are restricted to ocean disposal of dredged materials (see Figure 3-3). Ocean disposal is only proposed at one site of the two that are awaiting EPA designation.

Figure 3-9: Reach 7 Disposal Sites and Dredge Areas RM 3-29

4 SPECIES AND HABITAT INFORMATION – DESCRIPTION OF SPECIES, HABITAT USE, AND CRITICAL HABITAT

Seven salmonid fish runs having population segments that are federally listed under ESA as endangered, threatened, or proposed for listing as threatened spend a portion of their lives in the action area of the Columbia River. These species include 12 Evolutionarily Significant Units (ESUs) identified by NMFS[16] and 2 Distinct Population Segments (DPSs) identified by USFWS.[17] An additional species ESU that is not listed, but only a candidate for listing, is included here for future planning purposes only.

The ESUs and DPSs addressed in this BA are listed in Table 4-1. An ESU includes "any distinct population segment of any species of vertebrate fish or wildlife that interbreeds when mature" (Waples, 1991a). This population segment must be substantially reproductively isolated from other nonspecific population units and must represent an important component in the evolutionary legacy of the species. The definition of DPS is essentially the same as that for an ESU. The Services issued a joint policy describing DPSs in *Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act* (61 CFR 4722 February 7, 1996).

The listed ESUs are all salmonids (*Oncorhynchus*), a designation that includes a variety of salmon species as well as steelhead trout (*Oncorhynchus mykiss*). Although steelhead trout are commonly called trout, they are closely related to other salmonids scientifically grouped with them in the *Oncorhynchus* genus.

The listed ESUs fall into two life-history strategies. Ocean-type salmon rear in freshwater for only a few weeks to a few months before migrating to sea during their first year of life. Stream-type salmon spend at least a year rearing in freshwater prior to their downstream migration. The listed DPSs are bull trout (*Salvelinus confluentus*) and coastal cutthroat trout (*Oncorhynchus clarki clarki*).

Table 4-1: Federally Listed Salmonid ESUs/DPSs that Occur in the Action Area

Evolutionarily Significant Unit (ESU)	Status	Life History Type	Juvenile Life Stage In Lower Columbia River	Date Listed
Chinook (*Oncorhynchus tshawytscha*)				
Snake River spring/summer	Threatened[1]	Stream	Yearling +	4/22/92
Snake River fall	Threatened	Ocean	Subyearling	4/22/92
Lower Columbia River	Threatened	Ocean	Subyearling	3/24/99
Upper Columbia River spring	Endangered[2]	Stream	Yearling +	3/24/99
Upper Willamette River	Threatened	Ocean	Subyearling +	3/24/99
Chum (*Oncorhynchus keta*)				
Columbia River	Threatened	Ocean	Subyearling	3/25/99
Sockeye (*Oncorhynchus nerka*)				
Snake River	Endangered	Stream	Yearling +	11/2/91
Steelhead trout (*Oncorhynchus mykiss*)				
Snake River	Threatened	Stream	Yearling +	8/18/97
Lower Columbia River	Threatened	Stream	Yearling +	3/19/98

[16]NMFS is responsible for conducting consultations, pursuant to Section 7 of the ESA, for listed fish species that spend all or most of their lives in the marine environment.
[17] USFWS is responsible for conducting consultations, pursuant to Section 7 of the ESA, for listed fish species that spend all or most of their lives in the freshwater environment.

Evolutionarily Significant Unit (ESU)	Status	Life History Type	Juvenile Life Stage In Lower Columbia River	Date Listed
Middle Columbia River	Threatened	Stream	Yearling +	3/25/99
Upper Columbia River	Endangered	Stream	Yearling +	8/18/97
Upper Willamette River	Threatened	Stream	Yearling +	3/25/99
Coho *(Oncorhynchus kisutch)*				
Lower Columbia River/Southwest Washington	Candidate	Stream	Yearling +	7/25/95
Distinct Population Segments (DPS)				
Bull trout (*Salvelinus confluentus*)				
Columbia River	Threatened	Trout	Yearling +	6/10/98
Cutthroat trout (*Oncorhynchus clarki clarki*)				
Southwest Washington/Columbia River	Proposed Threatened	Trout	Yearling +	10/25/99

[1]Threatened: any species that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

[2]Endangered: any species that is in danger of extinction throughout all or a significant portion of its range.

Because individuals from each of these ESUs/DPSs may be present within the action area as juveniles or adults, or both, they may be affected by the Project directly or by alteration of the habitat they use.

For each ESU of the chinook, chum, coho, sockeye, and steelhead trout, all individuals move through the action area as juveniles on their migration to the ocean and again as adults during their return migration to spawn in the stream where they hatched. However, the amount of time spent in the action area during different life stages and at different seasons varies greatly among the ESUs. Because of the differences in the amount of time each of these salmon types spends in different portions of the system, changes to habitat affect them differently.

Only some individuals from the bull trout and cutthroat trout populations migrate into the action area to rear for a prolonged period. These individuals are referred to as migratory, and may either be fluvial (reside in rivers) or anadromous (migrating to a saltwater environment). The other individuals of these species are "resident"; they will stay in the stream where they hatched throughout their lives and will not migrate through the lower Columbia River. Prior to their upstream migration in the fall and winter, the migratory individuals may pass through the action area to rear in the ocean for a few months or they may stay within the action area to rear, never actually entering the ocean. Neither cutthroat trout nor bull trout spawn in the action area. Both species spawn higher upstream in the tributaries of the Columbia River Basin.

As adults, returning salmonids may take considerable time to move upstream or may move upstream rapidly once they reach the stream where they originally hatched. Because adults have much less restrictive habitat requirements than juveniles as they migrate through lower Columbia River areas, this BA focuses on the juvenile life stages of the listed species. Figure 4-1 shows some of the life stages of the listed species, as well as their relative sizes.

General life history and associated environmental conditions for ocean-type salmon, stream-type salmon, and trout are discussed in the following subsections. The major river category or reach type – riverine, estuarine, and river mouth – that the species types use during migration and rearing are also discussed. These reaches are illustrated in Figure 1-2.

Figure 4-1: Salmonid Sizes in the Lower Columbia River

4.1 Ocean-Type Salmon

Ocean-type salmon migrate downstream to and through the estuary as subyearlings, generally leaving the spawning area where they hatched within days to months following their emergence from the gravel. Ocean-type salmon ESUs in the Columbia River include some chinook ESUs (lower Columbia River, Snake River fall, and Upper Willamette River) and Columbia River chum salmon ESUs. Consequently, subyearlings commonly spend weeks to months rearing within the action area prior to reaching the size at which they migrate to the ocean. Young salmonids must undergo a physiological transition and develop enough strength, energy, and reserve capacity to adapt to and survive the physical and biological challenges of the ocean environment, as well as to successfully obtain prey in that environment. Juvenile salmonids appear to reach the threshold for this transitional state at a size of 70 to 100 mm. Before fish reach this size, their ocean survival would be difficult.

The first outbound migrants of the lower Columbia River fall chinook and chum may arrive in the action area as early as late February (Herrmann, 1970; Craddock, et al., 1976; Healey, 1980; Congleton, et al., 1981; Healey, 1982; Dawley, et al., 1986; Levings, et al., 1986). The majority of these fish are present from March through June. Outbound Snake River fall chinook begin their migration much farther upstream and arrive in the lower Columbia River approximately a month later. The chinook and chum subyearlings shown to the right were sampled in the shallow water of protected off-channel areas.

Ocean-type subyearlings arrive in the lower river and estuarine portion of the action area at a small size. The earliest migrants can be as small as 30 to 40 mm fork length (i.e., from snout to fork in the tail) when they arrive because some of these fish hatch only a short distance upstream from the action area. Later spring migrants are generally larger, ranging up to 50 to 80 mm. Subyearlings from the mid-Columbia and Snake Rivers tend to be substantially larger (70 to 100 mm) by the time they reach the lower Columbia River. The larger size of the lower Snake River fall chinook, compared with the lower Columbia River chinook and chum, likely indicates some differences in suitable habitat. The larger subyearlings from the Snake River can likely use a greater range of depth and current conditions than the subyearlings of the lower Columbia River ESUs can.

Salmon Subyearlings

Once ocean-type subyearlings arrive in the lower Columbia River, they may remain for weeks to months. Because these fish arrive small in size, they undergo extended lower river and estuary rearing before they reach the transitional size necessary to migrate into the ocean (70 to 100 mm). This larger size is necessary to deal with the physical conditions and predators they face in the ocean environment, as well as to be successful in obtaining prey in that environment. At growth rates of about 0.3 to 1 mm per day (Levy, et al., 1979; Argue, 1985; Fisher and Pearcy, 1990), the subyearlings require weeks to months to reach this larger size. During this time, young chinook increase by about 5 to 8 grams per day or approximately 6 percent of their body weight (Herrmann, 1970; Healey, 1980). Habitat characteristics in each of the three reach types support rearing and migration for the subyearlings, as discussed in the following subsections.

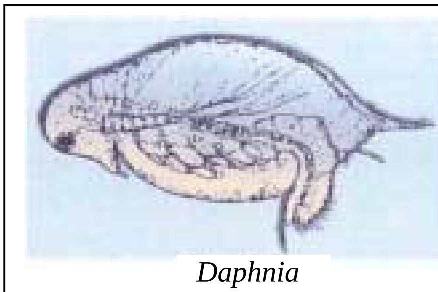
4.1.1 Riverine Reach

Numerous studies of Columbia River salmon have been conducted. Nearly all have begun at Bonneville Dam or farther upstream. A small body of information is available specifically for the riverine reach in the action area; however, it is likely the subyearlings use the lower Columbia River in the same manner that they use other lower river areas of salmon-bearing streams. Most lower mainstem rivers commonly are characterized by a low gradient, fine sediments, and relatively low water velocities that are gradually influenced by tidal forces as they approach the euryhaline estuary. The common physical and biological characteristics of these similar streams provide similar habitats that are inhabited by similar species and life stages of salmonids. Although the mainstem Columbia River shares most of these characteristics, it should be noted that its sediments are generally sandy rather than fine.

Ocean-type subyearlings migrate through the riverine reach of the action area during their downstream migration (about 150 kilometers [km]). Because of this, many spend some time rearing within the riverine reach; however, there is considerable variability in the freshwater rearing period of subyearling populations. Some subyearlings spawned in the lower reaches of coastal tributaries migrate almost immediately to marine areas following emergence from the gravel. Other subyearlings rear in freshwater for weeks to months, particularly those spawned well upstream in larger river systems such as the Columbia. The migration rate for subyearlings undergoing the rearing migration through the riverine reach is likely to be a few to 10 km per day. Subyearlings migrating directly to the estuary migrate at rates of 15 to 30 km per day (MacDonald, 1960; Simenstad, et al., 1982; MacDonald, et al., 1987; Murphy, et al., 1989; Fisher and Pearcy, 1990). Adult salmon returning to the Columbia River migrate through the river mouth throughout the year. The majority move through this area from early spring through autumn.

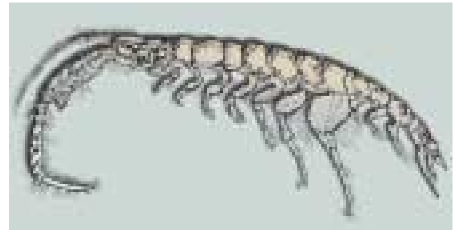
A number of physical characteristics in the riverine reach affect the quality and quantity of habitat available for salmonids. These include the availability of prey, temperature, turbidity, and suspended solids. These characteristics and their relationship to salmonid habitat are discussed in the following paragraphs.

Subyearlings are commonly found within a few meters of the shoreline at water depths of less than 1 meter. Although they migrate between areas over deeper water, they generally remain close to the water surface and near the shoreline during rearing, favoring water no more than 2 meters deep and areas where currents do not exceed 0.3 meter per second. They seek lower energy areas where waves and currents do not require them to expend considerable energy to remain in position while they consume invertebrates that live on or near the substrate. These areas are characterized by relatively fine grain substrates. However, it is not uncommon to find young salmonids in areas with steeper and harder substrates, such as sand and gravel.



Daphnia

Young chinook in the lower Columbia action area consume a variety of prey—primarily insects in the spring and fall and *Daphnia* from July to October (Craddock, et al., 1976). *Daphnia* is the major prey during the summer and fall months, selected more than other planktonic organisms. Young salmonids consume diptera, hymenoptera, coleoptera, tricoptera, and ephemeroptera in the area just upstream from the estuary (Dawley, et al., 1986). Bottom and Jones (1990) recently reported that young chinook ate primarily *Corophium*, *Daphnia*, and insects, with *Corophium being* the dominant prey species in winter and spring and *Daphnia* the dominant prey species in summer. Salmonids commonly feed on *Corophium* males, which apparently are more readily available than the larger females.



Corophium

Corophium is commonly discussed as a primary prey item of juvenile salmonids in the lower Columbia River. *Corophium salmonis* is a euryhaline species tolerating salinities in the range of zero to 20 ppt (Holton, et al., 1984). As shown by the above investigations, it is one of several major prey species consumed by juvenile chinook under existing conditions. No data are available that indicate its historical role in the diet of Columbia River salmon prior to substantial modification of the river system. Nutritionally, *Corophium* may not be as desirable as other food sources for young salmon. According to Higgs, et al. (1995), gammarid amphipods such as *Corophium* are high in chitin and ash and low in available protein and energy relative to daphnids and chironomid larvae.

As a result of substantial runoff from higher elevations, temperature conditions tend to be moderate in the riverine reach during the spring and early summer migration and rearing. Desirable water temperatures for young chinook and chum salmon during their migration downstream range from 6.7 to 13.3° C, with an optimum temperature of 10° C (Bell, 1991). Information on salmonids suggests that in freshwater environments smoltification might be suppressed at temperatures greater than 15° C and that optimal growth occurs in the 10 to 19° C range (Water Temperature Criteria Technical Workgroup, 2001). During late summer migration periods, the water temperatures can exceed 20° C and can approach lethal levels in shallow protected waters of the lower Columbia River. Young salmonids can acclimate to these higher temperatures over relatively brief periods of 24 hours or less (Brett, 1956). Brett (1956) also found they require less than 24 hours to acclimate at temperatures above 20° C. In freshwater, lethal temperature is greater than 23° C for juvenile salmonids and greater than 21° C for adult salmonids (Water Temperature Criteria Technical Work Group, 2001).

Adult salmon generally are not exposed to temperatures in a lethal range because of their capacity to avoid high temperatures, together with their propensity to remain in relatively open water until they reach spawning areas; however, high temperatures can delay their migrations. There are several examples in the Columbia River of adult migrations halting due to high or low water temperatures. In 1941, extremely high water temperatures (22 to 24° C) apparently resulted in chinook, sockeye, and steelhead adults congregating in small cold streams near Bonneville and Rock Island Dams (Fish and Hanavan, 1948). At the Okanogan River, Major and Mighell (1967) observed that temperatures greater than 21° C blocked sockeye migrations while stable or even rising temperatures below 21° C did not block migration.

Turbidity and suspended solids are a natural part of the riverine habitats occupied by young and adult salmonids. Turbidity refers to light attenuation by materials in the water; suspended solids refers to the amount of mineral particles suspended in the water column. For context, salmonids are produced in systems and estuaries where turbidities are commonly as high as 400 NTU (Murphy, et al., 1989). Turbidity at moderate levels of about 25 to 110 NTU is common in rivers with migrating salmon.

Turbidity can decrease the probability of predation on young salmonids. Gregory and Levings (1998) found that young salmon are less likely to be eaten by piscivorous fish at higher turbidities. Turbidity can also reduce the feeding efficiency of young salmonids. Gregory (1994) found salmonids had reduced foraging rates in turbidity above 150 NTU, but continued to feed at turbidities as high as 850 NTU. Noggle (1978) found salmonids stopped feeding at turbidities greater than 300 mg/L.

Gregory (1988) reported that the reaction distance of young chinook to benthic prey decreased greatly between zero and about 50 NTUs. From 50 to 250 NTUs, however, there was little change in reaction distance, partly because the fish were only reacting to prey within about 8 centimeters at 50 NTU. Growth of young steelhead and coho was reduced by chronic turbidity in the range of 20 to 50 NTUs in freshwater rearing (Sigler, et al., 1984). Turbidity during the spring freshet period may be lower in the

Columbia River under existing conditions than it was under historical conditions because the dams and associated reservoirs lower the water velocity.

Direct survival of young salmonids can be affected by high suspended solid loads. The lethal concentration found to kill 50 percent of a group (LC_{50}) of young salmonids under summer conditions (the most sensitive) is near 1.2 grams per liter (g/L) (Noggle, 1978). Smith (1978) determined the LC_{50} for chum to be greater than 2.5 g/L. The background suspended solid load in the lower Columbia River at 200,000 cfs is .02 g/L (Eriksen, SEI Presentation, 2001). Suspended solids do not appear to influence the homing of adult salmon. Whitman, et al. (1982), found that, although adult chinook tended to avoid Mount St. Helens ash at about 0.65 g/L, ash at average concentrations of 3.4 g/L in the Toutle River did not appear to influence homing performance.

4.1.2 Estuary

The estuarine reach is a complex physical habitat containing a large amount of shallow water habitat. The complex array of side channels, sandbars, and islands provides gentle to moderately sloping shallow water habitat with substrate ranging from sand to fine silt in backwater areas. As in the riverine reach, a number of physical characteristics affect salmon habitat in the estuary, including salinity, temperature, turbidity, and availability of prey.

Subyearling chinook and chum first enter the estuary at about the same time that they enter the riverine reach because some of the fry move rapidly to the estuary by mid-March rather than rearing in the riverine areas (Craddock, et al., 1976; Dawley, et al., 1986; Levy and Northcote, 1982; Healey, 1982; Hayman, et al., 1996). As chinook fry migrate to the estuary, they may remain in the low salinity or even freshwater areas for some time until they have grown somewhat larger (more than 75 mm) (Kjelson, et al., 1982; Levings, 1982; Levy and Northcote, 1982; MacDonald, et al., 1986; Shreffler, 1992; Hayman, et al., 1996). However, some chinook fry appear to move immediately to the outer edges and higher salinity portions of the estuary (Stober, et al., 1971; Kask and Parker, 1972; Sibert, 1975; Healey, 1980; Johnson, et al., 1992; Beamer, et al., 2000). Adult salmon returning to the Columbia River migrate through the river mouth throughout the year. The majority move through this area from early spring through autumn.

Ocean-type fish commonly have the capacity to adapt to highly saline waters shortly after emergence from the gravel. Tiffan, et al. (2000), determined that, once active migrant fall chinook passed McNary Dam 470 km upstream from the Columbia River's mouth, 90 percent of the subyearlings were able to survive challenge tests in 30 ppt seawater at 18.3° C. Other investigators have found that very small chinook fry are capable of adapting to estuarine salinities within a few days (Ellis, 1957; Clark and Shelbourn, 1985). Wagner, et al. (1969), found that all fall chinook alevins tested were able to tolerate 15 to 20 ppt salinity immediately after hatching.

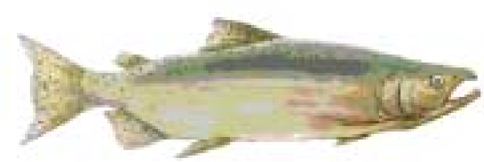
While tidal exchange with the ocean tends to keep estuary temperatures at moderate levels (10° to 20° C) throughout the time the outmigrants are present, spring and summer temperatures vary widely in shallow water because tidal flats are exposed by low tides during sunny midday periods. Consequently, young salmonids rearing in shallow water naturally experience a wide range of temperatures within periods of less than a day. The available observations of the behavioral reaction of young salmonids to temperatures in estuarine conditions are variable. Bessey (1976) found hatchery chinook and wild chum avoided water of 16° C. These fry responded immediately to increases of less than 1° C; however, the fry did not avoid rapid increases of more than 1° C per minute. Temperatures in the estuarine reach may range from zero to 26° C, but 12° to 14° C is optimum for young salmon (NMFS, 2000).

In the estuary, turbidity is important in relation to the ETM zone. The ETM zone is discussed in further detail in Section 6.1.4. Relatively high turbidity is a characteristic of the intermixing of freshwater and saltwater in the ETM. However, Jones, et al. (1990), concluded that, in the lower Columbia River, the standing stocks of benthic animals were highest in the protected tidal flat habitats, while those of epibenthic and zooplanktonic organisms were concentrated within the ETM. Because prey species have differing tolerances for salinity, increased salinity in the estuary results in different prey species being available to the rearing fry than those in the freshwater riverine reach, and in a change in the abundance of those prey species that are found in both the estuarine and riverine reaches. In addition, young salmonids in the estuary continue to eat many of the same organisms as are consumed in the riverine reach, but there are shifts in prey abundance. Young chinook and chum at Miller Sands in the upper estuarine reach feed primarily on the pelagic prey *Daphnia longispina* and *Eurytemora hirundoides,* the benthic prey *Corophium salmonis*, and chironomid larvae and pupae (McConnell, et al., 1978). Diet overlaps considerably among the different species. Many yearlings passing through the lower river were found to have empty or less than full stomachs (Dawley, et al., 1986).

4.1.3 River Mouth

As young salmonids leave the estuary, they migrate through the river mouth. Conditions in the river mouth are similar to those in other portions of the estuary – the major difference is the wave and current energy within the river mouth. The ocean area immediately outside the river mouth is characterized by high salinity during low to moderate flows and by high wave energy with no shoreline for protection.

It is likely that young salmonids pass through the river mouth from March through the autumn months during the same time they are present in the estuary. Some individuals may migrate out of the estuary early and other late in the general migration period of each ESU. Outside the river mouth, young salmonids enter the ocean, where high salinity and the absence of available shoreline require them to adapt to a pelagic life style. Pearcy, et al. (1990), found chinook in near-surface waters up to 46 km offshore from Oregon and Washington during the summer months, but absent from this area by mid-September. Orsi, et al. (2000), found juvenile chinook, chum, and pink salmon were most abundant in the shoreline (strait) waters of southeast Alaska during June and July when zooplankton abundance was highest. Food availability may also be a factor in the timing of Columbia River salmon migration; however, Brodeur (1992) concluded that food availability off the Oregon and Washington coasts was not a limiting factor.


Adult Chinook Salmon

Adult salmon migrate through the river mouth and adjacent ocean during their return to the Columbia River. During this period, they do not have any specific habitat requirements. The description provided above for their behavior in the riverine reach applies to the river mouth reach as well.

4.2 Stream-Type Salmon

Individuals of these species rear in freshwater, usually remaining in the stream where they hatched for a year or more before beginning their downstream migration to the ocean. Steelhead trout may rear in freshwater for several years before migrating to the ocean. Sockeye rear in lakes rather than streams. Stream-type ESUs include some of the chinook salmon ESUs (Lower Columbia and Upper Columbia spring), sockeye, coho, and steelhead. Stream-type or yearling salmon migrate to the ocean in their


Smolt

second year of life or later as relatively large smolts (generally 100 to 300 mm; see Figure 4-1) and move quickly through the action area within days to weeks.

Smolts undergo a physiological alteration in the spring that prepares them for migration and saltwater adaptation. Although fish in the various ESUs may migrate at somewhat differing times, smolts tend to be spring migrants that pass through the action area from early April through September. Migration timing varies with species and with distance between the action area and the stream where they hatched.

The larger size of the yearling smolts allows them to occupy a wider range of habitats. Smolts are commonly found farther from shore with a deeper distribution than ocean-type migrants. Johnsen and Sims (1973) compared beach seine and purse seine catches of chinook from fresh water and brackish water sites in the lower Columbia River. The majority of chinook collected from the shorelines by beach seine were in the range of 50 to 80 mm, while the majority of chinook collected from deeper water by purse seine were in the range of 90 to 150 mm. These larger fish collected from offshore locations are the smolt-size juveniles characteristic of stream-type salmon.

4.2.1 Riverine Reach

Stream-type smolts migrate at a relatively large size, commonly in the range of 100 to 300 mm. Their large size allows them to migrate rapidly downstream in the riverine reach because they have the physical capacity to deal with a much larger range of conditions than the subyearling ocean-type salmon.

Salmon smolts have been found over a substantial range of water depths, although they tend to remain near the water surface. Because yearlings are not shoreline-oriented like subyearlings, they are found throughout the near-surface water column and have commonly been sampled within the top 6 meters (20 feet) of the water column. Sims and Johnsen (1974) found that less than 5 percent of the chinook they collected using a beach seine near shore were yearlings or older.

Smolts are found in a wide range of current speeds as they move downstream. They tend to avoid low-velocity areas except during brief periods when they hold position against tidal or river currents. Recently, Schreck, et al. (1997, 1998, 2001), determined the swimming speed of yearling chinook and steelhead as they migrated from Bonneville Dam to the estuary. Yearling chinook moved about 140 km in 24 to 90 hours at a rate of 1 to 6 km per hour (0.7 to 3.7 miles per hour). Steelhead smolts have been found to migrate distances of 134 to 143 km in 32 to 90 hours, moving at an average rate of 3.3 km per hour (2 miles per hour) (Durkin, 1982; Dawley, et al., 1986). These fish either remain in the channel where substantial current occurs or are actively swimming at a high rate. Continuous tracking of some individual fish indicates that they remain in major channels where substantial downstream currents occur, and that they move between channels.

Yearling salmon are not associated with specific substrate types in the riverine or estuarine reaches. As stated previously, they tend to be water-column-oriented rather than shoreline-oriented and, consequently, are found in areas with a wide range of substrate types.

Yearling salmonids in the lower Columbia River generally eat the same types of organisms as subyearlings. In the lower Columbia River, they consume diptera, hymenoptera, coleoptera, tricoptera, and ephemeroptera. In the estuary, their diet changes to diptera, cladocerans, and amphipods (*Corophium salmonis, C. spinicorne, Eogammarus confervicolus*) (Dawley, et al., 1986). As in the riverine reach, Bottom and Jones (1990) found young chinook ate primarily *Corophium* in winter and spring and *Daphnia* in summer.

Yearling salmon have temperature and turbidity tolerances similar to those of subyearling salmon, as discussed in preceding sections.

4.2.2 Estuary

Stream-type smolts are present in the estuary primarily in May and June, with small numbers appearing earlier and later in the year.

Smoltification or physiological adaptation to migration and high salinity conditions begins in yearling salmonids before they begin their downstream migration. Salinity challenge tests have routinely shown that yearlings are capable of residing in moderate to high salinities (up to and greater than 20 ppt) long before they reach the saline water of the estuary. Sims (1970) reported that young chinook in the Columbia River that were marked one day in a freshwater area were found the next day in a high salinity area 43 km downstream. Movement from freshwater to saltwater apparently does not place high metabolic demands on young salmon (subyearling or yearling). Bullivant (1961) found no significant difference in oxygen consumption rates in young chinook when in freshwater, dilute seawater, or seawater (35.4 ppt). He interpreted this lack of difference in oxygen consumption rates as an indication that the energy expended on osmoregulation was a small portion of the total energy consumption.

Yearlings tend to stay away from the shorelines in deeper waters (Johnsen and Sims, 1973). Sims and Johnsen (1974) found that less than 1 percent of the chinook they collected in the estuary using beach seine close to the shore were yearlings. Most of the young salmon collected by NMFS in shoreline sampling at Jones Beach and adjacent areas were subyearlings, while yearlings tended to be collected in deeper water (Dawley, et al., 1979, 1981, 1984a, 1984b, 1985a, and 1986).

4.2.3 River Mouth

It is likely that fish move through this area relatively quickly, taking advantage of the outgoing tides that provide rapid currents into the open ocean. Open ocean conditions, characterized by weak currents and higher salinities, are considerably different from conditions in the riverine and estuary reaches. As with ocean-type salmon, steelhead trout and chinook were collected by Pearcy, et al. (1990), from near-surface waters up to 46 km offshore from Oregon and Washington during the summer months, but were absent from this area by mid-September. Food availability off the Oregon and Washington coasts was not a limiting factor for chinook (Brodeur, 1992). In a similar study, Orsi, et al. (2000), found that juvenile chinook, coho, and sockeye salmon were most abundant in shoreline (strait) waters of southeast Alaska in June and July when zooplankton abundance was highest. These waters differ from open ocean conditions because the strait offers greater protection from surf conditions.

4.3 Trout Species

Anadromous cutthroat and bull trout DPS populations migrate through and may rear within the action area as juveniles and adults. Cutthroat and bull trout occur in relatively small numbers in the lower Columbia River compared with the salmonid species (Bottom and Jones, 1990). The cutthroat trout DPS includes populations of Washington coastal streams from Grays Harbor to the Columbia River and its tributaries from the Dalles Dam to the MCR, and the Willamette River and its tributaries below Willamette Falls (see Appendices D-2 and D-3). Information on cutthroat trout in the lower Columbia River generally does not separate this DPS from individuals produced in the Willamette River and other upstream Columbia River tributaries. Published literature does not document the presence of bull trout in the lower Columbia River; however, information from a NMFS biologist indicates that sampling crews occasionally caught bull trout at Jones Beach and in the estuary in the 1960s and 1970s (Coley, pers. comm., 2001).

Subadult coastal cutthroat move into and through the lower river area in the spring. Many remain in the estuarine reach of the lower river prior to returning to the stream where they hatched in the late summer to fall. All of these fish appear to remain in the lower river or adjacent ocean areas for only a portion of a year before returning to freshwater. Subadult cutthroat commonly migrate to the lower river after at least 1 and up to 5 or 6 years of rearing in the stream where they hatched. In the lower river they appear to use both shallow water and offshore areas. Because of their large size, they tend to feed on larger invertebrates and small fish. Anadromous adults of these species commonly return to the lower river and adjacent ocean areas in subsequent years, where they remain for several months prior to their spawning migration to the stream where they hatched.

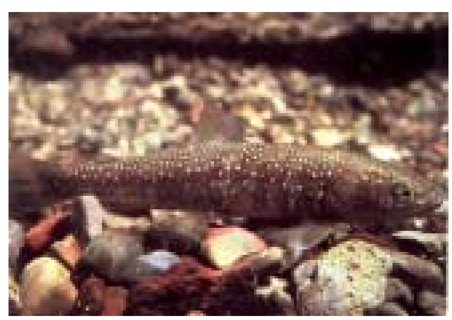
Anadromous cutthroat and bull trout are similar in that they represent only part of the total population of the species from any specific area (see Appendix D-3; Kraemer, 1994). Unlike salmon, many individuals of these species from within the same watershed do not migrate to the sea. For those individuals that do migrate, both species undergo prolonged rearing in freshwater of one to several years prior to migrating to the ocean. After a few months rearing in the estuary or nearby ocean areas, they return to spawn in later winter to early spring. Many individuals make multiple annual migrations to the ocean or estuary.

Anadromous cutthroat trout rear for 1 year to as long as 6 years in freshwater before beginning their migration to the ocean (Trotter, 1997). A review of data records at the NMFS Hammond Laboratory found records of cutthroat being collected from the lower Columbia River for most months in which sampling occurred (Young, pers. comm., 2001). Johnsen and Sims (1973) collected a substantial number of cutthroat trout in May and June, but only two in March, and none in July, implying that cutthroat trout migrate into and through the lower river primarily in the spring with the salmon smolts. Dawley, et al. (1979), concluded that downstream migration of juvenile and adult cutthroat appears to occur in April and May, peaking in early May. Loch (1982) provides data indicating that migration begins in mid-April, peaks in early May, and ends in early June. Cutthroat migrate downstream primarily in March to June (see Appendix D-3). Return of adult cutthroat into the Columbia River begins in early July, peaks in late July and early August, and ends by mid-September as these adults enter tributaries to spawn (Loch, 1982).

Juvenile cutthroat migrate downstream at a relatively large size. Loch (1982) reported the mean size of migrants to be 181 mm. Many cutthroat trout are more than 200 mm in length when they migrate to the estuary (see Appendix D -3).

4.3.1 Riverine Reach

The lower Columbia riverine reach provides both a migratory pathway and rearing habitat for cutthroat trout as they move downstream to the estuary and ocean (see Appendix D-3). The collection of cutthroat in purse seine catches and beach seine catches in the freshwater portion of the lower river (Johnsen and Sims, 1973; Sims and Johnsen, 1974) indicates that these migrants use both water column and shoreline habitats.



Bull Trout

Cutthroat trout feed on both invertebrates and small fish in the riverine reach, as they commonly do in streams (Trotter, 1997). Bull trout in freshwater feed primarily on whitefish (*Prosopium williamsoni*), sculpins, and young salmonids, although they also consume insects, amphibians, crayfish, and other available food (Kraemer, 1994). They appear to shift predominantly to fish, including young salmonids, as they increase in size and migrate downstream.

4.3.2 Estuary

Seining at Jones Beach, near the upper extreme of the estuary, at times has captured cutthroat trout offshore in the main channel (Dawley, et al., 1985a). Dawley, et al. (1985a), reported that cutthroat trout catches in the main channel declined during mid-summer months, while shoreline catches remained relatively high, suggesting that cutthroat trout reared in shallow littoral habitats at Jones Beach during the summer. Results of beach and purse seine sampling at other sites throughout the estuary, reported in Appendix D-3, indicated that cutthroat trout occurred in the channel throughout the estuary during spring and summer. In the shallows, they were present in the upper estuary spring through summer, but were seldom found in the lower two-thirds of the estuary until August and September. It is believed that young cutthroat trout may use side-channel habitat in the estuary, but no sampling has been conducted to confirm or refute this (see Appendix D-3).

Young cutthroat trout in estuarine areas eat crab larvae, insects, gammarid amphipods, young smelt, salmonids, and greenling (see Appendix D-3). Adult cutthroat in estuaries eat Pacific herring (*Clupea harengus paullasi*), threespine stickleback (*Gasterosteus aculeatus*), and bay shrimp (Loch, 1982). Young and adult bull trout (when present) in estuaries likely eat any small fish available, including the same species consumed in riverine and ocean areas.

Cutthroat Trout

4.3.3 River Mouth

Juvenile cutthroat trout are present in the coastal ocean waters in early summer, but are absent by September (Pearcy, et al., 1990). They are also found as far as 46 km offshore. Growth rates of juveniles during this period of ocean rearing were about 1 mm per day. The juvenile cutthroat trout collected off the Oregon and Washington coast had spent 1 to 4 years rearing in freshwater prior to migrating to the ocean. Pearcy, et al. (1990) found that young cutthroat trout fed predominantly on fish, including hexagrammids, scorpenids, northern anchovy (*Engraulis mordax*), and red Irish lord (*Hemilepidootus spinosus*). In late summer, euphausids, hyperiid amphipods, and decapod larvae were an important part of their diet. Growth of juvenile cutthroat trout in the ocean is about 1 mm per day (Pearcy, 1997). Kraemer (1994) reported that Puget Sound bull trout fed on Pacific herring (*Clupea harengus paullasi*), Pacific sand lance (*Ammodytes hexapterus*), and young salmon when in saltwater areas.

4.4 Critical Habitat

Section 4(a)(3)(A) of the ESA requires designation of critical habitat for listed species. The ESA defines critical habitat as the areas essential to the conservation of a listed species. Table 4-2 describes critical habitat as designated for 12 of the listed species within the action area. Critical habitat has not yet been designated for coho, bull trout, or coastal cutthroat trout.

Table 4-2: Critical Habitat Designations and Descriptions

Species		Date off Critical Habitat Designation	Description of Critical Habitat[18]
Chinook			
	Snake River spring/summer	December 28, 1993 (revised October 25, 1999)	Columbia River and estuary to confluence with Snake River, Snake River, and tributaries to Hells Canyon Dam
Chinook			
	Snake River fall	December 28, 1993	Columbia River and estuary to confluence with Snake River, Snake River, and tributaries to Hells Canyon Dam
Chinook			
	Lower Columbia River	February 16, 2000	Columbia River, estuary and tributaries from Grays and White Salmon Rivers to Willamette and Hood Rivers
Chinook			
	Upper Columbia River	February 16, 2000	Columbia River, estuary and tributaries upstream of Rock Island Dam, downstream of Chief Joseph Dam (excluding Okanogan River)
Chinook			
	Upper Willamette River	February 16, 2000	Columbia River and estuary, Clackamas and Willamette Rivers, and tributaries above Willamette Falls
Chum			
	Columbia River	February 16, 2000	Columbia River, estuary and tributaries downstream from Bonneville Dam
Coho			
	Lower Columbia River/SW Washington	Not yet designated	N/A
Sockeye			
	Snake River	December 28, 1993	Columbia River and estuary to confluence with Snake River, Snake River and tributaries from confluence with Columbia to confluence with Salmon River, Salmon River
Steelhead trout			
	Snake River	February 16, 2000	Columbia River and estuary to confluence with Snake River, Snake River and tributaries
Steelhead trout			
	Lower Columbia River	February 16, 2000	Columbia River, estuary, and tributaries between Cowlitz and Wind Rivers in WA,

[18] Critical habitat includes the riparian areas adjacent to listed rivers and streams. Riparian areas are defined as those areas adjacent to a stream that provide the following functions: shade, sediment transport, nutrient or chemical regulation, streambank stability, and input of large woody debris or organic matter (65 FR 7764). Critical habitat for salmonids in the Columbia River, as defined by NFMS, ends at the jetties at the MCR and does not include marine areas.

Species	Date off Critical Habitat Designation	Description of Critical Habitat[18]
		Willamette and Hood Rivers in OR
Steelhead		
Middle Columbia River	February 16, 2000	Columbia River, estuary, and tributaries (except Snake River) between Mosier Creek in OR and Yakima River in WA
Steelhead		
Upper Columbia River	February 16, 2000	Columbia River, estuary, and tributaries upstream of Yakima River, downstream of Chief Joseph Dam
Steelhead		
Upper Willamette River	February 16, 2000	Columbia River and estuary up to Willamette River, Willamette River and tributaries above Willamette Falls up to Calapooia River
Bull trout		
Columbia River	Not yet designated	N/A
Coastal cutthroat trout	Not yet designated	N/A
Southwest Washington/Columbia River		

In general, specific habitat characteristics have not been identified in the designation of critical habitat. Within the Columbia River critical habitat, chinook are likely to be most sensitive to changes related to the Project because subyearling chinook require protected shoreline habitat during their migration and rearing. This habitat is commonly shallow with current velocities not exceeding 0.3 meter per second. Critical habitat incorporates the water, substrate, and adjacent riparian zone to 300 feet inland.

5 CURRENT SYSTEM FUNCTION

Section 5 describes the relationships among ecosystem components and the factors that determine salmonid production and ocean entry. A conceptual model was constructed of the lower Columbia River ecosystem relationships that are significant for juvenile salmonids. The model provides a framework for evaluating potential environmental effects on listed salmonid species. In discussions of the complex nature of the lower Columbia River and its estuary, the science panel convened by SEI identified the need for a consistent framework for understanding the lower Columbia River ecosystem. The conceptual model discussed in this chapter is based on the agencies' discussions of a common framework. The framework is to be used to understand and explain the estuarine ecosystem and its functions as they relate to salmonids.

Figure 5-1 depicts flows from the general processes (ocean and river) through the more specific characteristics of this ecosystem. It is also compatible with other conceptual tools that may be used in biological assessments, including the NMFS' concept of Properly Functioning Conditions (PFC). The PFC format for large river estuarine ecosystems is discussed further in Section 5.2. A technical discussion of the conceptual model characteristics is presented in Appendix E.

5.1 The Conceptual Model

The conceptual model for juvenile salmonids of the lower Columbia River provides an integrated diagram of the major ecosystem links that affect ecosystem structure and function as they relate to juvenile salmonid production and ocean entry. The specific objectives of the lower Columbia River model are to:

- Provide an ecosystem-level scientific framework for evaluating the Project
- Identify links among physical-chemical and biological indicators
- Aid in the identification of ecosystem-based processes that link salmon and potential effects of the Project
- Develop a systematic methodology to evaluate monitoring and adaptive management opportunities

The conceptual model is generally formatted to describe the present state of the ecosystem, using general factors and identifying how they influence a specific function, as shown below:

Controlling Factors →
Ecosystem Structure →
Ecosystem Function →

The **controlling factors** refer to those general physical processes that influence all river conditions. The **ecosystem structure** refers to how those factors are manifest, specifically in the lower Columbia River system. The **ecosystem function** is then determined by output of indicators specific to the ways in which the ecosystem structure functions to produce salmonids for ocean entry.

The goal of the model is to present a clear, scientifically based hypothesis in diagram form that illustrates major connections among processes, indicators, and pathways within the system. Because of the complexity of the ecosystem, these connections are illustrated in a series of figures representing a set of linked submodels based on the functional pathways of the system. These pathways include processes within the river system (e.g., habitat formation, tides, bedload transport, accretion/erosion); specific components, or indicators, within the system (e.g., habitat types, food types, physical properties); and the pathways through which these processes and indicators combine to affect the ecosystem (e.g., primary productivity, food web). The processes and indicators used in the conceptual model are introduced in bold type throughout this chapter. Habitat types are shown in italics on first reference.

Figure 5-1 illustrates the relationships among the major functional pathways that affect salmonids in the lower Columbia River. These pathways support the growth and survival of juvenile salmonids, which then result in the output shown in Figure 5-1 and in the model – i.e., juvenile salmonid production and ocean entry. Salmonid production and ocean entry depend on several functions, including development of habitats, production of food to fuel the food web, and ability of salmonids to access and use these habitats. The culmination of these functions results in growth and survival of salmonids and their ultimate entry into the ocean.

Figures 5-2a and 5-2b illustrate the habitat-forming processes and the various indicators that lead to development of the habitat types that support juvenile salmonid growth and survival, again leading to the output of juvenile salmonid production and ocean entry. These figures depict the ecosystem function as it relates to salmonids in the action area. Figure 5-2a presents these processes for the ocean areas, while Figure 5-2b presents them for the areas that lie within the Columbia River system. Other figures in this section illustrate each of the major function pathways, with additional supporting information for the conceptual model located in Appendix E.

The requisites provided to salmonids in the lower Columbia River ecosystem are a function of the ability of salmonids to access habitats (i.e., habitat opportunity) and the amount of food available within these habitats (i.e., habitat capacity) (Bottom, et al., 2001). In turn, opportunity and capacity depend on the development and functioning of viable habitats. These habitats are formed and maintained by physical and chemical forcing factors. Significant interactions affect both the development of habitat and the support provided by habitats to salmonids. These interactions include habitat succession rates and patterns, disturbance regimes, landscape connectivity, and diversity among salmonid ESUs and DPSs. The model highlights the complexity of the factors supporting juvenile salmonid production and ocean entry.

5.1.1 Habitat-Forming Processes

Habitats are formed primarily by the interaction of hydrodynamic forces and sediment supply. In the lower Columbia River, both the river and the ocean influence the estuarine hydrodynamics. River discharges and volumes are regulated by precipitation, temperature (i.e., freeze and thaw), and reservoir operations. Ocean processes, including tidal action and waves, interact with river processes, including currents and sediment transport, in the lower Columbia to produce the estuary's complex hydrodynamics. The net result is deposition (accretion) of suspended sediments to form flats and carving (erosion) to form shallow and deep channels. Where sediment deposits can form islands, marsh and swamp vegetation can develop. These marshes and swamps are dissected by shallow channels, which allow fish access to edges of the vegetated areas.

The indicators and processes involved in the formation and maintenance of lower Columbia River habitats are illustrated in the Habitat-Forming Processes Pathway shown in Figures 5-2a and 5-2b. The main factors affecting or explaining habitat development include salinity and bathymetry (i.e., elevation of substrate). Salinity and bathymetry are indicators of system function. Additional indicators include **suspended sediment, bedload, woody debris, turbidity,** and **accretion/erosion**. **Woody debris** is a special case of a habitat-forming indicator that is directly input into the estuary from upstream sources.

Figure 5-1: Integrated Model for Juvenile Salmonids in the Lower Columbia River

Figure 5-2a: Habitat-Forming Process Pathway – Ocean

Figure 5-2b: Habitat-Forming Process Pathway – River

Shallow water and flats form in intertidal sandy or muddy areas where sediments are somewhat unstable and where the elevation is not high enough for emergent marshes to develop. If the **turbidity** levels are low enough to allow sufficient light penetration for plant growth, these areas may develop submerged vegetation such as eelgrass.

Bedload transport describes the process through which the channel bottom sands are moved along the surface of the riverbed. In sandy riverbeds, like those in the lower Columbia River, **bedload transport** shapes portions of the bed into a series of sand waves. The hydraulic forces of the river move these waves downstream as sediment erodes from the upstream face, deposits in the downstream trough, and is then buried by additional material eroded from the upstream face. The topography created by these sand waves is the **bathymetry** of the river.

The movement and deposition of large **woody debris** are also affected by the hydrologic process. It is deposited on the flats, along channel edges, and in marshes and swamps. **Woody debris** creates a vertical structure to which fish often orient and also provides "micro" habitats that can trap organic matter, which can be rich in invertebrates.

Another important factor in habitat development is the mixing of freshwater and saltwater in the lower river, which results in a **salinity** gradient in the estuary (Figure 5-3). The zone of mixing varies significantly in location, depending on river flow and tides. Because it is denser than freshwater, saltwater moves upstream along the bottom where it forms a salt "wedge" below the overlying layer of freshwater. Intense mixing proportional to river depth occurs at the area between freshwater and saltwater. Because plants and animals are adapted to certain salinity ranges, the salinity level, as well as seasonal and spatial patterns, strongly influences where species occur in the lower Columbia River.

As in many other estuaries, turbidity from suspended sediment and plankton is moderate to high in the lower Columbia River. High river flows and heavy wind and wave activity can increase turbidity significantly. Because plants require light to grow, turbidity affects how deep plants can grow below the water surface. Higher turbidity means that plants can grow only very near the surface of the water. Rooted aquatic plants, such as eelgrass (*Zostera marina*), are generally limited to very shallow depths in the estuary because of turbid water (Dennison, et al., 1993).

Table 5-1 is a list of salinity ranges that occur in estuaries. Of relevance to juvenile salmonids is the oligohaline zone, brackish water areas of only slight salinity, where juvenile salmonids go through a physiological transition to a saltwater environment. Juvenile ocean-type salmon may spend a considerable period of time in the oligohaline zone, where they require adequate food supplies and refuge from predators to survive and grow.

Table 5-1: Salinity Zones

Zones	Salinity Range (ppt)
Hyperhaline	> 40
Euhaline	30.0 – 40
Mixohaline (brackish):	0.5 – 30
Polyhaline	18.0 – 30
Mesohaline	5.0 – 18
Oligohaline	0.5 – 5
Fresh water	< 0.5

Source: Modified from Cowardin, et al., 1979.

Figure 5-3: Mixing Zone Between Freshwater and Saltwater

In the Habitat-Forming Processes Pathway (see Figures 5-2a and 5-2b), all of these dynamics and interactions culminate in the expression of habitat types important to salmon in the lower Columbia River. The habitats created are shown in the Habitat Type Pathway (Figure 5-4).

5.1.2 Habitat Types

The habitats most directly linked to salmonid in the lower Columbia River include the *tidal marshes and swamps*, *shallow water and flats*, and the *water column.* As described in Section 5.1.1, these habitats are the result of highly dynamic physical processes interacting in the river and ocean of the action area. Habitat types are generally defined by specific elevation ranges (Figure 5-5).

Tidal marshes and swamps generally occur from about MHHW. Tidal marshes begin at lower tidal elevations, slightly above MLLW although rare at lower than these elevations, and swamps occur at or above MHHW (Thomas, 1983). Thomas (1983) based these characteristics on a comparison of 19 vegetation types where low, medium and high elevations are based on a diurnal range (MLLW-MHHW) averaging 8 feet (where low equals 2.5 to 4 feet above MLLW; medium equals 4 to 6.5 feet above MLLW; and high equals above 6.5 feet). Ocean-type juvenile salmonids use the edges of these marshes to feed, and the edges of shallow channels within the marshes as refugia and feeding areas (Figure 5-6). Consequently, access to the edges at high tide and development of low-tide refuge areas near or within marshes are critical to lower river ocean-type juveniles. Channel order (the number and width of channels) and channel depth are also functional characteristics of a marsh area. The aquatic edge is considered to be an important factor governing the exchange of organisms, and the connectivity associated with the channels offers more opportunity to marsh access (Shafer and Yozzo, 1998). Although there are no empirical data on this relationship for the lower Columbia River, smaller marshes would provide limited salmonid access and only limited nearby low-tide refuge areas. Large marshes provide access to a much greater amount of edge and provide low-tide refuge.

Tidal marshes can be divided into saltwater marshes and freshwater marshes, each characterized by a distinctive vegetation type. Tidal marshes include tidally influenced areas all the way up to Bonneville Dam, as well as extensive tidal freshwater marshes in the lower Columbia River, particularly those in Cathlamet Bay.

Shallow water and flats occur throughout the intertidal zone and into the shallow subtidal zone in waters up to 6 feet deep. Benthic algae (largely benthic diatoms) develop on tidal flats and in the shallow subtidal zone within the system.

Water column habitat refers to waters that are greater than 6 feet deep and can be characterized by depth. For example, the upper 3 to 10 feet of the water column can have a very different community from that found at greater depths. The stratification is caused both by the salinity variation and the light penetration by depth.

The water column habitat is essentially the location where phytoplankton and floatable organic matter occur within the lower Columbia River system. Both phytoplankton and zooplankton respond to salinity changes within the habitat. Freshwater plankton dominate the fresh and oligohaline portions of the water column upstream, and plankton tolerant of greater salinity dominate the estuary and the river mouth of water column habitats.

5.1.3 Habitat Primary Productivity Pathway

A major function of the habitats is to produce food used by the ecosystem. Habitat **primary productivity** refers to the amount of material (biomass) produced over time during plant growth that occurs within each habitat type. Primary productivity is driven by **light** (Figure 5-7) and is supported by inorganic nutrients (e.g., nitrate, phosphate). Inorganic nutrients enter the system from the upstream watershed and the downstream ocean currents and through the breakdown and recycling of organic matter within the system. Factors that affect the distribution of the plants within the system include the habitat-forming processes of **sedimentation, erosion, salinity**, and **turbidity** (see Figures 5-2a and 5-2b). One example of the interaction of these processes is that, as turbidity is increased, light in the water column is reduced (Figure 5-7). This can result in less plant growth as well as limit the depth at which plants will grow. The Habitat Primary Productivity Pathway is illustrated in Figure 5-8.

Phytoplankton are the primary producers within water column habitat. Phytoplankton are single-celled plants, primarily diatoms, that drift within the water column. There are two types of phytoplankton in the lower Columbia River: **imported phytoplankton**, which are freshwater species produced in large quantities in the upstream watershed (particularly in the reservoirs behind the mainstem dams), and **resident phytoplankton**, which are produced within the lower Columbia River. Resident species can be freshwater, euryhaline, or marine species.

Primary productivity within the *shallow water and flats habitat* results mostly from benthic algae, single-celled plants in or on the sediments. Shallow water habitats can also produce filamentous algae and flowering grasses such as eelgrass; however, the majority of primary productivity within the river's shallow water areas comes from benthic algae.

Primary productivity within *tidal marsh and swamp habitat* comes from the marsh and swamp vegetation, which includes emergent plants, shrubs, and trees.

As illustrated in the Food Web Pathway (Figure 5-9), live plant material and detritus are the primary sources of organic matter in the food web used by salmonids in the lower Columbia River.

5.1.4 Food Web Pathway

Another key function of the lower Columbia River is to provide for salmonids. A food web reflects who eats what in an ecosystem. It helps develop an understanding of the pathways by which trophic groups of the food web obtain food. In addition, when habitat types and habitat-forming processes change over time and affect productivity patterns, the resulting food web shifts can provide insight about processes that potentially limit the growth of groups within the food web.

The base of any food web is the plant material produced over time or the **primary productivity** within each habitat type. This food web base also includes detritus (dead plant material). Macrodetritus in the system are large, complex forms of dead plants, primarily in tidal marsh macrodetritus. Microdetritus are dead, simple-celled plant materials or organic particles. Microdetritus can be in the form of **imported microdetritus** if they are derived from imported phytoplankton, or **resident microdetritus** if they are derived from resident phytoplankton. Small animals that shred the larger plant matter and microbes, including bacteria, protozoa, and fungi, facilitate the breakdown of detritus. In addition to making the organic matter useful to the food web, these breakdown processes recycle inorganic nutrients needed by the plants for primary production.

As illustrated in the Food Web Pathway (Figure 5-9), juvenile salmonids are members of a complex food web in the lower Columbia River. The model represents only the salmonid portion of the total food web for the system, which is far more complex. The organic energy sources at the base of this web are shown on the left side of the figure and, as stated above, are from the primary producers of biomass as depicted in the Habitat Primary Productivity Pathway (Figure 5-8). The model illustrates energy transfers through live plants that can be eaten directly or detritus that can be incorporated into the food web through detritivores (animals that eat dead and decaying plants and animals).

Although the Food Web Pathway does not show the relative amounts of food energy derived from each primary producer type, it does illustrate that salmonids can and do eat invertebrate prey species that are supported by resident and imported plankton, detritus, and tidal marsh and swamp plant material. The relative amount of food and food energy depends on the abundance of each resident habitat type (e.g., tidal marshes) and the input of nonresident material from upstream sources. Input of nonresident material is determined from upstream production, primarily by production in the reservoirs behind the dams, which is regulated by Bonneville Dam flow rates.

Several types of feeders make up the next level up the food chain from the primary producers and their detritus. For purposes of the conceptual model, the next level has been grouped as follows:

Mobile macroinvertebrates are large epibenthic organisms that reside on the river bottom and feed on bottom sediments. The main examples of macroinvertebrates in the lower river include sand shrimp (*Crangon franciscorum*), mysids (*Neomysis mercedis*), and Dungeness crab (*Cancer magister*). Mysids are the primary macroinvertebrates that are relevant to the salmonid food web.

Deposit feeders are benthic animals that feed by consuming organic matter in sediments. For this conceptual model, the term deposit feeders refers to both surface and subsurface deposit feeders, which include marine annelids (polychaetes), and freshwater annelids (oligochaetes), and benthic crustaceans.

Suspension feeders are organisms that feed from the water column itself. For zooplankton and benthic/epibenthic organisms, this is accomplished primarily through "filter feeding" (extracting organic matter from the water column by pumping or siphoning the water through their systems). Among the most abundant species found in the stomachs of salmonids is the planktonic cladocera suspension feeder *Daphnia pulex*.

Suspension/deposit feeders are benthic and epibenthic organisms that feed on or at the interface between the sediment and the water column. Perhaps the most abundant species found in the stomachs of salmonids is the benthic amphipod *Corophium salmonis*.

Floating insects (larvae and adults) appear to be important in the diet of most of the species and age classes in the salmonid food web. Many of these insect types feed on live tidal marsh plants.

As described in Section 4, subyearling chinook, an example of juvenile salmonids in general, feed primarily on the bottom but in shallow water while they are in the lower Columbia River, whereas older (yearling) fish of all species feed primarily on zooplankton in the water column.

Where these prey species are found is also important. Because outmigrating juvenile salmon are often found in the upper 6 feet of the water column, they probably do not eat benthic (bottom dwelling) prey in deeper parts of the estuary (i.e., more than 6 feet deep). Consequently, the primary depth range for salmonids feeding on benthic prey is the intertidal zone and down to a depth of about 6 feet below Extreme Lower Low Water. Insects, *Corophium*, and mysids located in shallow habitats such as tidal marshes, tidal channels, and flats are more available to salmonids at higher tides. On the other hand, planktonic prey such as *Daphnia* and copepods are available at any stage of the tide.

Figure 5-4: Habitat Type Pathway

Figure 5-5: Major Habitat Types in the System

Figure 5-6: General Pattern of Lower Columbia River Use by Juvenile Salmonids

Figure 5-7: Effect of Turbidity on Light Penetration Through the Water Column

Figure 5-8: Habitat Primary Productivity Pathway

Figure 5-9: Food Web Pathway

5.1.5 Growth Pathway

Salmonid feeding results in growth of the animals in preparation for their outmigration to the north Pacific. The Growth Pathway depicted in Figure 5-10 incorporates feeding as well as other factors that are involved in producing salmonid growth in the lower Columbia River.

The inputs leading to the Growth Pathway (Figure 5-10) indicate the progression from physical factors involved in defining habitats in the lower Columbia River through the way in which these habitats work to produce food for salmonids. The Growth Pathway highlights the factors involved in producing both the appropriate amount and type of food prey and the access by juvenile salmonids to productive feeding areas.

The characteristics of the food web, such as the abundance of insects versus the biomass of nonresident microdetritus and where prey and other nutrients are distributed, are important in determining the relative contribution of these food sources to the growth of salmonids. The "Food Abundance and Distribution" and "Habitat-Specific Food Availability" boxes in the Growth Pathway (Figure 5-10) address these feeding factors. The actual location and structure of feeding habitats are important because salmonids need first to be able to access feeding habitat and, while there, be able to find the prey items.

Salmonids are adapted for using a complex mosaic of many habitat areas as they migrate downstream and during their residence in riverine and estuarine systems in the Pacific Northwest. Therefore, coupled with **habitat-specific food availability, feeding habitat opportunity** needs to exist for salmonids to feed within the set of habitats. As described in Section 4, juvenile salmonids primarily frequent very shallow water areas, especially the subyearling chinook. They benefit most from prey produced in tidal marshes and marsh channels, on the edges of natural side channels, and on flats (Figure 5-6). When water level is low, salmonids are believed to congregate at the edges of natural side channels and pools, which become low-tide refuges.

This mosaic of habitats used by salmonids is referred to as **habitat complexity**. An absence or reduction in the natural complexity of habitats available may affect the salmonids' ability to reach food resources needed for growth. **Conveyance** is the opportunity for salmonids to move over flats and into tidal marsh systems as the water level rises and falls with the tide and with river flow (Figure 5-6).

Connectivity refers to links and spatial arrangements among habitats in the mosaic of changing habitat areas. For juvenile salmonids in the lower Columbia River, this refers to favorable access among viable feeding, rearing, and refuge habitats along the migratory corridor. Blockages, interruptions of corridors, or modifications of habitat may prevent or limit access to productive feeding habitats. For example, a culvert may block fish access to tidal marsh behind a river levee. Large numbers of overwater structures may limit the ability to migrate or the migration habits of fish traveling along the shoreline. Because fish are adapted to use a wide but linked set of habitats, maintaining access among habitat types is important to feeding habitat opportunity. **Connectivity** is illustrated in the Growth Pathway (Figure 5-10).

Low current, shallow areas provide productive feeding areas for salmonids. Available information suggests that velocities of 30 centimeters per second or less are best for optimal foraging opportunity (Bottom, et al., 2001). Because salmonids are visual predators, **turbidity** and uneven **bathymetry** may limit their ability to prey (see Section 4). The concepts of **velocity field,** shallow **bathymetry**, and **turbidity** are illustrated in boxes at the left of the Growth Pathway (Figure 5-10).

Figure 5-10: Growth Pathway

Finally, there are **energy costs** that each individual animal expends to feed. These include locating prey, feeding behavior, avoiding predators, and processing energy from prey consumed. In general, fish prefer high-energy food that provides the most energy per unit of effort. Anything less than this will, theoretically, produce suboptimal growth rates.

5.1.6 Survival Pathway

Besides growth, a variety of factors interact to affect the ultimate survival of salmonids in the lower Columbia River. The Survival Pathway (Figure 5-11) shows the links among these factors.

Salmonid survival depends on the ability of fish to grow and migrate through the lower Columbia River system. As shown in the previous pathways, a complex set of factors can control or affect growth and migration.

Factors that can negatively affect survival include contaminants, predation, suspended solids, temperature and salinity extremes, stranding, entrainment, and competition. These factors are discussed below.

Contaminants include chemicals that can affect the health of salmonids. They can be taken up directly through the water column or through contaminated prey (food web). The prey of juvenile salmonids may obtain contaminants via their food. For example, contaminants deposited on the bottom along with organic matter may be ingested by deposit-feeding animals, which are in turn eaten by juvenile salmonids. These contaminants may affect the health (physiological integrity) of fish and may result in **disease** as well as a reduced ability to physiologically adapt to saltwater, avoid predators, forage effectively, and seek and find shelter.

Predation is a major factor affecting salmonid survival in the lower Columbia River. Birds, including Western grebes, cormorants, gulls, terns, and great blue herons, are known to prey on small fish that may include young salmon. Fish predators are less well known, but larger fish, including sculpins, have been documented as having salmon in their guts.

Suspended solids, which can be a major contributor to **turbidity**, affect migratory ability by reducing the ability of salmonids to see prey. Data indicate that the threshold concentration for survival of ocean-type salmonids is on the order of 1 g/L.

Temperature and salinity extremes typically stress fish. Salinity extremes can occur during extreme low-flow conditions, which allow more salt farther up into the estuary. Temperature extremes can occur in the summer over shallow flats and channels during low tides.

Stranding can occur when fish are washed up onto higher ground by waves or ship wakes, or if they are caught for extended periods of time in a shallow pool during an extended low tide. Fisheries biologists have observed stranding of salmonids in the lower Columbia River system.

Entrainment refers to the uptake of fish during dredging. Because dredging occurs primarily in the deepest portions of the channel, bottom-dwelling fish would be more susceptible to being entrained. Surface-oriented fish, such as salmonids, may be less susceptible.

Finally, **competition** among members of the outmigrating population may play a role in survival; however, little is understood or documented regarding the effects of competition in the lower Columbia River.

Figure 5-11: Survival Pathway

Adaptive behavior improves the probability that salmonids will survive. The adaptive behaviors of predator avoidance, feeding optimally in the system, and ability to find refuge are all enhanced if fish are healthy. As described in several pathways above, salmonid health depends on physiological integrity, as well as the availability and quality of habitats.

5.2 Pathways and Indicators

The conceptual model is a way to show the interactions and relationships within a system that, when they are operating properly, help to characterize the system as a whole. This conceptual model for juvenile salmonids consists of several submodels that represent the primary functions of the system. Each of these submodels is composed of several components that link together common relationships associated with maintaining the primary functions. These submodels are the "pathways" in which the components operate for a common function. Each of the components, in turn, may have many states, values, or characteristics that are indicative of the function of the pathway at a particular time; therefore, these components are called "indicators."

Baseline conditions used here are representative of the current state of the indicators used in the conceptual model for the lower Columbia River ecosystem. The effects of the proposed Project are determined by measuring the incremental changes caused by the Project. However, the evaluation of whether the incremental changes are important to the ecosystem functions as a whole depends on an understanding of how current conditions and the proposed incremental changes to those conditions deviate from optimal conditions or PFCs for the ecosystem as a whole.

The concept of PFCs is used by NMFS to assess the effects of proposed incremental changes to the ecosystems used by salmonids. The pathways and indicators of the conceptual model follow the NMFS PFC concept, although NMFS-approved guidelines for PFCs in large rivers and estuaries are not yet available. A PFC format, which is currently being drafted, is an effort to establish estuarine and shoreline PFCs in Washington. For river mouth estuaries such as the Columbia River, the PFC is defined as the sustained presence of natural habitat-forming processes in an estuary and associated tributary rivers, upslope, and marine environs to create conditions conducive to the long-term survival of native species. The PFCs produce conditions where the carrying capacity of a native species population is met, the population is resilient to environmental change, and it is allowed to follow its natural evolutionary pathways. "Natural" in this context is not intended to imply pristine.

6 EFFECTS ANALYSIS

Section 6 uses the conceptual model, which is described in Section 5, to evaluate potential effects from the proposed Project. Focusing the effects analysis on the changes in ecosystem indicators of function helps to clarify how the proposed Project may influence listed salmonid production, successful ocean entry, and return migration. It also clarifies influences on critical habitats and the related processes where small, indirect changes may influence ecosystem functions in the long term.

Section 6.1 is an analysis of how the proposed project activities may have the potential to change the 38 ecosystem indicators that are parts of the conceptual model. It is only intended to identify potential changes to each indicator as a first step in the ultimate analysis of potential effects on listed species. The analysis is specific to effects that might occur to the indicator that is addressed and, as such, it is not intended to address potential effects to other related indicators. The analysis in Section 6.1 for each indicator builds upon all previous related indicator analyses. Therefore, it is important to read all of Section 6.1 to fully understand the analysis. The analysis addresses all direct and indirect effects to the indicator, as well as potential effects from interrelated and interdependent activities. Changes to an ecosystem indicator that are identified in Section 6.1 are carried into Section 6.2 for further pathway analysis. These indicator changes will be evaluated to determine how the Project affects ecosystem pathways identified in the conceptual model.

Any changes to the pathways that are identified in Section 6.2 are also carried forward into Section 6.3, which focuses on whether the identified impacts to the pathways will affect salmonids. Accordingly, Section 6.3 provides the actual determination of potential project effects. This section also includes a discussion of short-term and long-term effects. Short-term effects are defined as those that are identifiable now; long-term effects are those that are not identifiable now but may occur over the 50-year life of the Project. Beginning 5 years after construction, the dredging and disposal plan consultation will be reviewed by both the Corps and the Services at 5-year intervals. Section 6.4 presents information about activities not included in this BA: development of additional ports or port facilities and the Willamette River.

6.1 Project Effects on Indicators

This section of the BA is an evaluation of the potential effects of the proposed action on the 38 individual indicators identified in the conceptual model for the lower Columbia River (see Section 5 and Appendix E for details of the conceptual model). The analysis identifies whether there is potentially an effect and, if so, quantifies, as much as possible, the potential effect. If quantification is not possible, an estimate of the effect in nonquantitative terms is provided. The tools used for these analyses also include two numerical models (Appendices G and H) that predict project-influenced changes in depth, velocity, and salinity, and deliberations by the Biological Review Team (BRT), an interagency team of specialists who reviewed the Project's effects.

6.1.1 Suspended Sediment

The Project is not expected to cause changes to sediment supply or river hydraulics that would alter the rates of suspended sediment transport. The Columbia River bed consists of alluvial sand deposits that vary in thickness from 400 feet in the estuary to 100 feet at Vancouver (Gates, 1994). The dredging would generally remove 3 feet or less of that riverbed material from approximately 46 percent of the 600-foot-wide navigation channel. The hydraulic effects of dredging 3 feet deeper are very small (see Section 6.1.7, Bathymetry). Given the consistency in suspended sediment measured at different times and locations (see Section 2.3.1.1, Suspended Sediment), those small hydraulic changes are not likely to affect suspended sediment transport rates. Therefore, the volume and rate of suspended sediment transport in the Columbia River will not be changed by the Project.

Some temporary increases to suspended sediment concentrations are expected to occur during construction and maintenance dredging activities, as the result of both dredging and the disposal of dredged materials. These dredging and disposal activities will occur in both estuarine and riverine environments. Disposal will occur also in the open ocean, beyond the river mouth. There are no anticipated actions that would cause effects to this indicator in the area above Vancouver.

During the course of the consultation process, there was consideration of whether changes to the channel depth would alter ship wakes and cause associated increases to suspended sediment. The discussion in this section indicates that no alteration of current ship wake patterns will occur.

6.1.1.1 Suspended Sediment Caused by Dredging Activities

The channel deepening project will require 18 to 19 mcy of construction dredging and 90 mcy of maintenance dredging (12 mcy above and beyond the 78 mcy required to maintain the present 40-foot channel) during the first 20 years of the project (Corps, 1999a). For the long-term analysis, it has been assumed that dredging volumes for years 21 through 50 would remain constant at 3 mcy per year. The action of dredging that material will resuspend sediment and cause an increase in suspended sediment concentrations. Because most of the resuspended sediment is expected to be sand, it is expected to settle rapidly.

There are three types of dredges likely to be used on this project: pipeline, hopper, and mechanical. Pipeline and hopper dredges are expected to do the majority of the dredging, with a mechanical dredge being used only in the rock areas during construction. Each dredge has specific actions that can cause resuspension of sediment. A pipeline dredge would resuspend material at the river bottom, around its cutterhead. A hopper dredge would resuspend sediment at the bottom, around the draghead, and also at the surface if there is overflow water discharged from the hopper. A mechanical dredge would resuspend sediment at the bottom, where the bucket disturbs the riverbed, through the water column as the bucket is raised, and from the barge if there is overflow water.

A single pipeline dredge operating at 20,000 cubic yards per day in the Columbia River would potentially resuspend between 1 and 150 cubic yards per day (1.6 to 205 tons per day) of sediment, which is mainly (99 percent) sand (Eriksen, SEI Presentation, 2001). Because this resuspension will occur very near the bottom, the sand will redeposit very quickly. The fall velocities for Columbia River sands are in the range of 1 to 2 centimeters per second, so sand resuspended 1 meter off the bottom would redeposit in approximately 1 to 2 minutes. Because the riverbed sediment in the navigation channel is generally (99 percent) sand, the downstream release of sediment should be very small (less than 1 percent fine components released). Even under low flow conditions of only 100,000 cfs, the downstream increase in suspended sediment from the less than 1 percent fine components (silt, clay, organics) could range from near zero mg/L to less than 1 mg/L. Given that the LC_{50} for salmonids is 1.2 g/L of suspended sediment (see Section 4.1.1) and the amount identified here is three orders of magnitude less than that level, this effect is expected to be insignificant.

A hopper dredge operating at 20,000 cubic yards per day in the Columbia River has been estimated to resuspend 90 cubic yards per day (120 tons per day) at the draghead (Eriksen, SEI Presentation, 2001). This sediment would behave the same as described above for a pipeline dredge. The sand would redeposit in approximately 1 to 2 minutes and a very small amount of fine sediment would be released downstream. The hopper dredge would also release sediment with its overflow water from the hopper. This release would tend to be composed of silt and clay that can remain in suspension longer than sand.

The upper limit of this release would therefore be the volume of fine sediments in the dredging volume (i.e., less than 200 cubic yards per day [less than 1 percent of 20,000 cubic yards per day]). The total downstream increase in suspended sediment could approach 1 mg/L at a river discharge of 100,000 cfs, composed mostly of fine sediment discharged at the surface.

A mechanical dredge has a greater potential for resuspending sediment than do pipeline or hopper dredges operating in similar sediments (WES, 1999). For this project, however, the mechanical dredges would probably only be used in the rock areas at Warrior Rock and Longview. Those areas have a combined volume of approximately 300,000 cubic yards. Test pit observations indicate that fine sediments make up only a small portion of the total rock volume, suggesting that the release of sediments would be correspondingly small, but larger than for either pipeline or hopper dredging techniques.

Riverine Reach

Construction and maintenance dredging are expected to occur throughout this reach. During the 2-year construction period, pipeline dredges are expected to remove 18 mcy (3 mcy of operations and maintenance [O&M] material related to the 40-foot channel, 12 mcy of new 43-foot channel work, and 3 mcy of O&M material related to the 43-foot channel). After construction, the maintenance volumes in this reach are expected to be around 5 to 7 mcy per year and then steadily decline to 1 to 2 mcy per year in 20 years as the river reaches equilibrium with the deeper navigation channel. Pipeline dredges are expected to do most of the maintenance dredging. Hopper dredges may be used occasionally during construction and maintenance to remove small amounts of material.

Based on the above information on sediment resuspension from pipeline and hopper dredges, the increase in suspended sediment caused by a single pipeline dredge would range between 1 cubic yard per day and 150 cubic yards per day and a hopper dredge could produce up to 200 cubic yards per day. Therefore, during construction when two pipeline dredges would be working in this reach, there would be an increase in suspended sediment of 2 cubic yards per day to 300 cubic yards per day. Those volumes would convert to suspended sediment concentration increases of zero mg/L to 1 mg/L at a river discharge of 100,000 cfs and zero mg/L to 0.6 mg/L at 200,000 cfs. Because the dredged sediment is 99 percent sand, the downstream concentration increases are very likely to be near the lower end of those ranges. A third dredge, either a hopper or pipeline, might be used for short periods during the construction period to do construction or maintenance work. When operating, the third dredge would generate an additional increase in suspended sediment of less than 1 mg/L. As discussed in Section 2, the background suspended sediment concentrations at 100,000 and 200,000 cfs are less than 10 mg/L (2,000 cubic yards per day) and around 20 mg/L (8,000 cubic yards per day), respectively. The combined background and project-related suspended sediment concentrations are well below known salmonid impact levels.

A pipeline dredge will generally do maintenance dredging in this reach, with some work by hopper dredges. Generally, only one dredge would be operating in this reach at any time, but occasionally a hopper dredge may also be working at the same time. The suspended sediment increases during maintenance dredging would range from near zero mg/L to slightly more than 1 mg/L for a river discharge of 100,000 cfs. The maintenance impacts would ordinarily occur from May through September.

Somewhat higher suspended sediment concentration increases than those discussed above may occur when vessel berths at ports along the Columbia River are dredged to accommodate deeper-draft vessels. The material in these berths and slips may not be as sandy as those in the main channel; there may be more silts and clays. Impacts from suspended sediments resulting from berth deepening would be short term because the volumes to be removed are relatively small, as listed below:

- Terminal 6 Berths 603, 604, and 605 at Port of Portland: 24,500 cubic yards

- U.S. Gypsum at St. Helens: 12,500 to 14,000 cubic yards
- United Harvest Berth at Port of Kalama: 250,000 cubic yards

Estuary

Suspended sediment concentrations in the estuary will be influenced by construction and maintenance dredging in the estuary and upstream riverine reach. During the 2-year construction period, hopper dredges are expected to remove approximately 11 mcy (3 mcy of O&M material related to the 40-foot channel, 6 mcy of new 43-foot channel work, and 2 mcy of O&M material related to the 43-foot channel) from the estuary. After construction, the maintenance volumes in this reach are expected to be around 2 to 4 mcy per year and then steadily decline to 1 to 2 mcy per year in 20 years as the river reaches equilibrium with the deeper navigation channel. Pipeline and hopper dredges are expected to do the maintenance dredging.

During construction when two hopper dredges would be working in this reach, there would be an increase in suspended sediment of less than 400 cubic yards per day. The resuspended sediment from hopper dredge overflow water would be composed mostly of fine sediment. That volume would convert to suspended sediment concentration increases of less than 2 mg/L at a river discharge of 100,000 cfs and less than 1 mg/L at 200,000 cfs. A third dredge, either a hopper or pipeline, might be used for short periods during the construction period to do construction or maintenance work. When operating, the third dredge would generate an additional increase in suspended sediment of less than 1 mg/L. During construction, the estuarine increases in suspended sediment would be in addition to the increased suspended sediment caused by dredging in the riverine reach.

As discussed in Section 2, the background suspended sediment concentrations in the estuary vary with time and space. The inflowing suspended sediment from the riverine reach is distributed throughout the estuary, where local erosion and deposition and mixing with ocean waters can greatly alter the concentrations. A fine-grained sediment particle may remain in suspension within the estuary for up to 4 months, depending on flow conditions.

During maintenance operations, increased suspended sediment could be caused by dredging in either the estuary or upstream riverine reaches. Hopper dredges could work anywhere within the estuary or river, but pipeline dredges will generally be limited to areas upstream of Tongue Point (RM 18). Typically, one or two dredges could be working in the estuary or river at any time during the May through September maintenance season. However, three dredges may occasionally do maintenance work simultaneously. The increases in suspended sediment caused by maintenance dredging will depend on the number and type of dredges working at any one time, but would generally be limited to less than 2 mg/L at 100,000 cfs. The maintenance impacts would ordinarily occur from May through September.

River Mouth

No dredging activities associated with the Project would occur within the river mouth reach; however, there would be increases in suspended sediments caused by the upstream dredging. The increases for both construction and maintenance dredging would be the same as those described for the estuary.

The MCR Project is a separately authorized project. Maintenance dredging at the MCR is not part of this BA and is covered by a separate consultation.

6.1.1.2 Suspended Sediment Caused by Disposal Activities

Material dredged from the existing navigation channel is currently placed in a combination of shoreline, upland, and in-water (or flowlane) disposal sites (Corps, 1999a). Disposal from construction and maintenance of the proposed action is planned for 29 upland sites, a gravel pit, an in-water mitigation site, three shoreline disposal sites (for beach nourishment), in-water (flowlane) (generally in 50- to 65-foot depths throughout the Project), and in the ocean at the deep water site.

At upland disposal sites, dredge material will be placed in diked disposal areas that will contain the sands and the return water. Return water will be held in settling ponds until it meets applicable Oregon or Washington water quality standards at an appropriate point of compliance after dilution for suspended sediment.

Shoreline disposal is an unconfined disposal method used by pipeline dredges. The pipeline discharges the sediment/water slurry onto the beach, and the sand settles out of the slurry as it flows toward the shoreline. The beach is built out into the river and the return water flows freely into the river. There is an increase in suspended sediment adjacent to the beach that then dissipates as it moves downstream. Suspended sediment concentrations in these plumes have not been measured. However, surface measurements taken by the Corps 50 feet offshore from a shoreline disposal operation found increases of 5 to 15 NTUs. Based on the relationship between NTUs and silt/clay concentrations observed in the Columbia River, that would equate to increases of approximately 10 to 30 mg/L (Eriksen, SEI Presentation, 2001). The shoreline plume will mix with the river water as it moves downstream, and the suspended sediment concentrations will diminish to near background levels. This is not expected to create a potential impact because this activity will occur at shoreline sites, which, as explained previously (see Section 3.2.7), are highly disturbed, erosive areas with low or no benthic populations. Consequently, salmonids do not feed or rear in these areas. In Carlson (2001), juvenile salmonids were found to migrate rapidly past shoreline disposal areas, likely because of disturbance in the area and lack of suitable habitat.

Flowlane disposal is most commonly done by hopper dredges, but may occasionally be done by a pipeline dredge. The sediment from a hopper dredge would be released over a period of approximately 5 minutes at a depth of 20 to 30 feet. The sediment concentration in the plume would depend on river currents, dredge speed, and the amount of fines (silt and clay) in the disposal material, as the sand will fall quickly to the bottom. In the Columbia River the dredged sediment is less than 1 percent fines, but that would be further reduced by the fines discharged by the overflow water during dredging. A single disposal from a 3000-cubic-yard hopper dredge would therefore release less than 30 cubic yards of fine suspended sediment. Measurements taken by the Corps during hopper disposal operation found increases of zero to 10 NTUs. Based on the relationship between NTUs and silt/clay concentrations observed in the Columbia River, that would equate to increases of approximately zero to 20 mg/L (Eriksen, SEI Presentation, 2001). The plume will begin in the bottom 20 to 30 feet of the water column and will mix with the river water as it moves downstream. The suspended sediment concentrations will diminish to near background levels as the plume moves downstream.

During flowlane disposal, the sediment from a pipeline dredge would be released at a depth of 20 feet or more. Because the dredged material is discharged in a slurry, the sand will fall to the riverbed in about 5 minutes, while nearly all the fines can be expected to be released into the water column. In the Columbia River the maximum fines release for a pipeline dredging operating at 20,000 cubic yards per day would be less than 200 cubic yards per day. As described previously, some of the fines would be released during dredging, but most would be released during the flowlane disposal operation. The total downstream increase in suspended sediment could approach 1 mg/L at a river discharge of 100,000 cfs. Given that the LC_{50} to salmonids is 1.2 g/L of suspended sediment (see Section 4.1.1) and the amount identified here for both hopper and pipeline dredges is approximately three orders of magnitude less than that level, this effect is expected to be insignificant.

Ocean disposal is done by hopper dredges. The sediment from a hopper dredge would be released at a depth of 20 to 30 feet below the surface and the sediment would fall to the ocean bottom in a plume. Sediment concentrations in the plume would depend on the fall velocities of the material being disposed, the depth of the disposal site, the ocean currents, and the speed of the dredge during disposal. Most of the sand will settle to the bottom, while the fines may remain in suspension for some time. A single ocean disposal from a 4,000-cubic-yard hopper dredge would therefore release a sediment plume containing less than 40 cubic yards of fine suspended sediment.

Riverine Reach

Disposal activities will occur in many areas throughout the riverine reach. Most of the disposal for both construction and maintenance will be upland (see Appendix C), but some flowlane disposal is likely and shoreline disposal will occur at Sand Island (O-86.2). The suspended sediment increases in this reach will be small because the vast majority of the disposal will be at upland sites where settling ponds will reduce suspended sediments in return flows. The flowlane disposal is expected to be about 0.5 mcy during construction and 0.5 to 1.0 mcy per year over the first 20 years of maintenance. Shoreline disposal at Sand Island is expected to be required at 3- to 4-year intervals to replace eroded beach sand. The total suspended sediment released by dredging and disposal during flowlane and shoreline disposal operations would be limited to the fines content of the sediments. As a result, there could be a suspended sediment increase of less than 200 cubic yards per day, resulting in an average downstream concentration increase of less than 1 mg/L at 100,000 cfs.

Estuary

During construction, the disposal in this reach will be about 2 mcy of flowlane disposal around RM 30 to 40 and, as described in Section 8, construction material will be used to form the Lois Island Embayment Restoration. This will consist of a two-step process that will require materials to be dredged from the navigation channel with a hopper dredge, then temporarily deposited in the Tongue Point turning basin. From this point, materials would then be moved to the Lois Island Embayment using a pipeline dredge. Two dredges, a hopper and a pipeline dredge, might be used simultaneously to do this work, so the maximum suspended sediment increase from dredging and disposal would be less than 400 cubic yards per day. That rate would convert to average downstream suspended sediment concentration increases of less than 2 mg/L at a river discharge of 100,000 cfs and less than 1 mg/L at 200,000 cfs. However, there would be plumes with higher concentrations that would move with the currents. The concentrations in these plumes would not exceed the observed increases from hopper discharge of zero to 10 NTUs (zero to 20 mg/L). Again, given that the LC_{50} to salmonids is 1.2 g/L of suspended sediment (see Section 4.1.1) and the amount identified here is two to three orders of magnitude less than that level, this effect is expected to be insignificant.

Throughout the first 20 years of channel maintenance, flowlane disposal will occur in and adjacent to the navigation channel throughout the estuary. The annual flowlane disposal volumes are expected to begin at about 1 mcy per year and decline to about 0.7 mcy per year in 20 years. Upland disposal will occur at Welsh, Pillar Rock, and Rice Islands. Shoreline disposal will occur at Skamokawa and Miller Sands. The increases in suspended sediment caused by upland and shoreline disposal will be similar to those described above for the riverine reach.

The inflowing suspended sediment from the riverine reach, including any increases from dredging and disposal, would be distributed throughout the estuary. Because of the location of the flowlane disposal in the estuary, most of the sediment released will be carried to the open portion of the estuary, downstream of RM 23. Once flow enters the estuary, local erosion and deposition processes, and mixing with ocean waters, can greatly alter the suspended sediment concentrations.

River Mouth

This reach will be impacted by disposal at the ocean site and by the increases in suspended sediments caused by the upstream dredging and disposal. The increases from upstream for both construction and maintenance dredging would be the same as those described for the estuary.

Ocean disposal, using a 4,000-cubic-yard hopper dredge, will result in the release of discrete sediment plumes containing less than 40 cubic yards of fine suspended sediment. The individual plumes will drift with the ocean currents and eventually disperse. The rate at which the plumes disperse will depend on several factors, including river discharge, tide, ocean currents, ocean upwelling, wave size and direction, winds, and disposal location.

Adult and juvenile salmonids can occur in the vicinity of the ocean disposal site during their ocean life-history stage. Both adults and juveniles are feeding in this area, primarily on pelagic organisms. Dredged material disposed of in the ocean will result in only a short-term impact to the water column over the site. It is unlikely that this would significantly affect feeding behavior and may, in fact, provide additional food in the disposal material.

6.1.1.3 Suspended Sediment Caused by Ship Wakes

Ship wakes breaking on shore can erode sediment and then suspend the eroded material. Larger waves contain more energy and have greater capability to mobilize sediment. Accordingly, during the consultation process, there has been analysis of whether the proposed activities would lead to more frequent or larger ship wakes.

While the proposed channel improvements would increase the efficiency of river commerce, it is not anticipated to increase the volume of river traffic. Accordingly, there is no expectation of more frequent ship wake instances occurring as a result of the proposed improvements.

In addition, a recent analysis of technical studies related to ship wakes indicates that little if any change is expected (Hermans, SEI Presentation, 2001) as a result of channel deepening activity. Hermans analyzed several mechanisms by which ships generate waves. The analysis found that for deep-draft vessels the most important wave mechanism in the Columbia River would be the primary or “suction” wave generation. This mechanism depends on the "blockage" ratio, which is the ratio of the cross-sectional area of the ship to that of the channel (Figure 6-1). Given the proposed increase in channel depth and the expected increase in vessel draft, the ratio changes very little. The blockage ratio of a 43-foot draft vessel in a 43-foot channel is only 1 to 5 percent higher than that of a 40-foot draft vessel in a 40-foot channel. However, for the much more numerous smaller ships that would not increase their draft, there would be a slight decrease (in the range of 1 to 5 percent) in the blockage ratio with the deeper channel. Thus, while 43-foot draft ships may generate slightly larger wakes than occur now, this would be offset by most ships producing slightly smaller wakes. As a result, the overall changes in wave size caused by the deeper channel are negligible. Application of equations presented in Weggel and Sorensen (1986) to deeper draft vessels in a deeper channel support this conclusion.

Figure 6-1: Cross-Sectional Representation of Vessels in 40-Foot and 43-Foot Channels

Riverine Reach

Deep-draft ship traffic in this reach averages around five to six transits per day, including both inbound and outbound ships. Most ships currently transiting the Columbia River have sailing drafts of less than 30 feet, with less than 10 percent of the outbound ships having drafts of 40 feet or more (Corps, 1999a). These Panamax grain vessels and Panamax and larger container vessels carry between 50 percent and more of the cargo tonnage leaving the Columbia River in a 43-foot channel (Daly, 2001). Abbe (1990) estimated that ship wakes accounted for between 4 and 24 percent of the observed erosion of sand from a shoreline disposal site on Puget Island. Given the location, beach conditions, and river hydraulics of that site, that estimate should be applicable to all the sandy beaches on the river. The hydraulic effects from the ships also disturb the bottom sediments and create a small but undetermined amount of suspended sediment and related turbidity.

In the future, the actual number of transits will depend on trade volumes but are expected to be similar with either a 40-foot or 43-foot channel. As explained above, the resulting effects of a 43-foot channel on ship wakes would be small and could be either positive or negative, depending on vessel draft. Because of this, shoreline erosion caused by ship wakes is not expected to change. The changes in the hydraulic effects on the river bottom have not been calculated, but should follow the same trend as ship wakes. Therefore, because most ships will have more underkeel clearance (distance between the ship's hull and the riverbed), sediment resuspension and turbidity could be slightly less in a 43-foot channel.

Estuary

The vessel traffic and ship draft patterns described for the river reach will also apply to the estuary. Therefore, there are no anticipated changes in estuarine shoreline erosion or suspended sediment related to ship wakes or hydrodynamics.

It should also be noted that under existing or future conditions, the deepest draft vessels, those with more than a 37- to 38-foot draft, can be expected to transit the estuary at or just prior to high tide. This timing suggests that much of the silt or clay resuspended by a vessel downstream of Tongue Point (a reach that includes most of the ETM zone) would be discharged to the ocean during the ebb tide flow.

River Mouth

See Estuary, above.

6.1.1.4 Conclusion

Settling of suspended sediment caused by dredging, disposal, and ship wakes is expected to be rapid. Based on the data indicating that less than 1 percent of the dredged material is fine enough to remain in suspension following disposal, the Corps estimates that disposal of construction-related dredging will contribute up to 180,000 cubic yards of suspended sediments over the 2-year construction period. Background suspended sediment loads for the same 2-year period have been estimated at 4 mcy. This is a maximum increase of 4.5 percent in the suspended sediment load and generally equates to less than 1 mg/L increase in suspended sediment concentrations.

Riverine Reach

In riverine areas where neither dredging nor disposal is occurring, there should be no observable increase in suspended sediment concentration. In areas where dredging and disposal activities occur, there may be noticeable, short-term increases in suspended sediment near hopper dredges and shoreline disposal operations. Dredging operations are likely to cause downstream suspended sediment increases of zero to 2 mg/L, depending on the number and type of dredges operating.

There will be no change to suspended sediment from ship wakes.

Estuary

See Riverine Reach, above.

River Mouth

Upstream dredging operations are likely to cause suspended sediment increases of zero to 2 mg/L, depending on the number and type of dredges operating. Disposal of sediments will occur at open-water ocean sites beyond the river mouth. Ocean disposal will result in the release of discrete sediment plumes of fine suspended sediment that will slowly disperse. There should be no change to suspended sediment from ship wakes.

6.1.2 Bedload

This section of the BA addresses bedload aspects related to side-slope adjustment as well as volume and rate of bedload transport. This analysis of side-slope adjustment assumes that the Project is not expected to alter volume or rate of bedload transport.

6.1.2.1 Potential Reduction in Volume of Bedload Caused by Removal of Channel Materials

Sand from upstream areas is one of the sources of material for habitat-forming processes (accretion) in the estuary. This sand is important to the formation of tidal marsh and swamps and shallow water and flats habitat. An issue arose during the reconsultation process concerning the potential to reduce the quantity of bedload moving downstream to the estuary. This was based on the concern that removing sand from the upstream channel would cause a concomitant reduction in the amount of sand (habitat-forming material) that would reach the estuary.

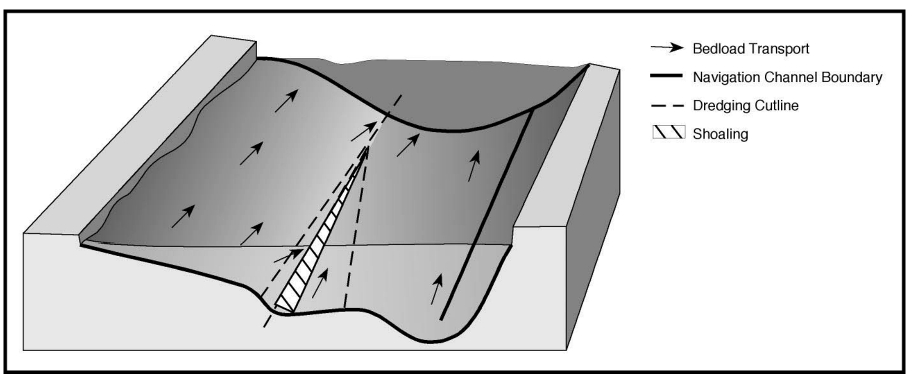


Figure 6-2: Relative Magnitude and Direction of Bedload Transport in a Typical Reach of the Columbia River

The amount of sand that reaches the estuary is based on the river's sediment transport potential and the available sediment supply. Sediment transport potential is a function of hydraulic parameters such as depth, velocity, slope, and discharge. The available sediment supply comes from upstream discharges, the riverbed and banks, and tributary inflows. As noted above, dams and flow controls have significantly changed flow and sediment transport (see Sections 2.3.1.1, Suspended Sediment and 2.3.1.2, Bedload).

The Project will have inconsequential effects on river hydraulics (see Section 6.1.7.4, Bathymetry – Conclusion). Therefore, the Project will not significantly alter the sediment transport potential. This finding is supported by the fact that sediment inflow to the dredging area from upstream of Vancouver (RM 106.5) is essentially the same as the sediment transport at RM 54, two reaches with markedly different hydraulic conditions. The river's transport potential is fully used before the Project area. Therefore, reducing the amount of sand in the Project area does not affect the amount of sediment transported to the estuary.

Of the three sediment sources, the sediment inflows from upstream and tributaries will not be altered; therefore, the amount of sand available for transport could only be affected by the project if it were to deplete the sand available in the riverbed and banks. The Columbia River bed consists of alluvial sand deposits that vary in thickness from 400 feet in the estuary to 100 feet at Vancouver (Gates, 1994). The volume of sand that will be dredged over the life of the project is a tiny fraction of the total volume of sand in the riverbed; thus, the project will not reduce the available sand supply in the riverbed.

6.1.2.2 Potential Effects to Salmonid Habitat Caused by Side-Slope Adjustment

Side-slope adjustment is a process that will occur after the channel is deepened. After the initial dredging to deepen the channel, the channel slopes will be steeper than can be maintained naturally. These slopes will go through a process of change that will result in a slope that can be naturally maintained at a new dynamic equilibrium.

Side-slope adjustment will not occur quickly. It will not result in slumping or caving in of the channel slopes. This natural process will take an estimated 5 to 10 years to reach the new dynamic equilibrium. Essentially what will happen is that the bedload that is moving downstream will change direction until the adjustment is complete. As described in Section 6.1.6, Accretion/Erosion, the volume and rate of the bedload movement is not expected to change. Only the direction of the sand particles will change as the bedload naturally moves downstream. Figure 6-2 illustrates the side-slope adjustment process. Without the creation of the steeper slopes, bedload would generally move in a downstream direction. After the channel is deepened, the sand particles (bedload) will shift direction along the face of the channel edge (cutline). Instead of moving generally downstream, gravity will cause it to move down the slope until a new dynamic equilibrium is reached. As noted above, this process of side-slope adjustment could continue for several years until the gravitational forces reach a new dynamic equilibrium.

Side-slope adjustment may cause lateral erosion toward the shoreline. Most of this side-slope adjustment will occur in deeper areas of the river (see Section 6.1.10, Water Column Habitat), but some shoreline areas might be affected. Natural shoreline areas of the Columbia River are composed of hard silt/clay or rocky material; they have been very stable over the past 100 years or so. Previous deepenings of the channel and maintenance dredging have not caused side-slope adjustments to the natural shoreline areas. Side-slope adjustments caused by the deeper channel will not occur in natural shoreline areas because they are stable (Corps, 1999a). This means that no tidal marsh and swamp habitat (see Section 6.1.8, Tidal Marsh and Swamp Habitat) would be affected by side-slope adjustments. Side-slope adjustments could cause shoreline erosion in areas with sandy beaches. These beaches are prone to side-slope adjustment erosion because the noncohesive sands are easily eroded and do not have stabilizing vegetation. Because there are not any naturally occurring sandy beaches in the Columbia River, these are areas that have been created in the past by disposal of dredged material. This type of habitat is included in the category described in Section 6.1.9 (Shallow Water and Flats Habitat). Specific sites where side-slope adjustment might occur are limited and are identified below for each project reach.

Side-slope adjustment could cause the shoreline of sandy beaches to move laterally or shoreward. Given the range of sandy beach slopes found by Abbe (1990) of 0.10 to 0.02 foot per foot, a 1-foot change in riverbed elevation at the shoreline could result in 10 to 50 feet of lateral shoreline erosion on shoreline disposal sites. Over time, this shallow water and flats habitat will tend to move shoreward into former areas of created beach that have slowly eroded. This gradual erosion allows for new shallow water and flats habitat to establish. As discussed above, erosion would occur over a number of years; therefore, the quantity of shallow water and flats habitat would be expected to remain constant over time. This habitat type would migrate the eroded areas shoreward, but the gross amount of area that is 6 feet or shallower would remain the same. Likewise, the rate of bedload movement would be the same, only in a different direction, so it would not be expected that the quality of aquatic habitat would change. See Section 6.1.9, Sahllow Water and Flats Habitat, for a discussion of the effects of this erosion.

Riverine Reach

Side-slope adjustments that would affect shallow water and flats habitat might occur in the riverine reach at five locations – RM 99, 86, 75, 72, and 46 through 42. These are all past shoreline disposal sites, and only the RM 86.2 site is proposed for use in this reach due to the proximity of the dredging needed in this section of the river. These sites do not include tidal marsh and swamp habitat. Side-slope adjustment could cause 10 to 50 feet of lateral shoreline erosion of sandy beaches in each of those areas; however, this is not expected to reduce salmonid habitat (see Section 6.1.9, Shallow Water and Flats Habitat).

Estuary

The reach at RM 12 has undergone significant side-slope degradation, but it is not an adjustment related to the channel depth. Side-slope adjustments that would affect shallow water and flats habitat might occur at RM 22.5, Miller Sands. This site is proposed for use throughout the Project life. Miller Sands forms the southern shoreline in that area, and the proposed beach nourishment disposal is expected to limit lateral erosion. This area is currently eroding at a rapid pace. Side-slope adjustment is not expected to increase this rate of erosion; consequently, no project impact is expected.

River Mouth

Under this proposed action, no dredging will occur in this reach; therefore, side-slope adjustment caused by the Project will not occur here.

6.1.2.3 Conclusion

The proposed Project will not affect transport potential because the amount of material to be removed from the system is not the limiting factor for bedload movement; flow available to move the material is the limiting factor and the Project will not affect flow. The Project will not significantly reduce the sand supply. The proposed Project will result in some side-slope adjustment as a result of altered bedload transport direction within the action area. This process will not affect water column or tidal marsh and swamp habitats. The side-slope adjustment process will take 5 to 10 years, and over that time shallow water and flats habitat at six shoreline disposal sites will tend to migrate laterally. All of these shoreline sites have been used in the past due to the proximity of the dredging. Two of the six shoreline sites, at RM 86.2 and RM 22.5, will be used throughout the project life.

Because the bedload transport rate during side-slope adjustment is the same rate at which normal bedload transport would occur without the Project (just in a different direction), the quantity and quality of shallow water and flats habitat is expected to remain constant. The Corps is proposing to verify this conclusion through a monitoring survey of habitat conditions before, during, and after completion of the project (see Section 7).

Riverine Reach

The proposed Project could cause side-slope adjustment that might cause shallow water and flats habitat at five past beach nourishment sites to migrate laterally.

Estuary

The proposed Project could cause side-slope adjustment that might cause shallow water and flats habitat at RM 22.5 to migrate laterally.

River Mouth

The Project will not cause any side-slope adjustments in this reach.

6.1.3 Woody Debris

Woody debris is present in natural settings primarily within the forested wetlands portions of large rivers and estuaries such as the lower Columbia River. Here the debris provides potential refuge structures along side channel shorelines. During the consultation process, two potential means for affecting woody debris input to the system were identified: changing water levels and changing salinity.

6.1.3.1 Role of Woody Debris in the Ecosystem

Changes in water level that would either dry out or flood existing tidal marsh or swamp habitat could result in such habitat no longer providing appropriate conditions and being distant from aquatic habitat. This would likely require water level changes on the order of more than 19 inches to produce changes in the tidally influenced area.

In addition, substantial increases in salinity could result in the loss of trees providing woody debris. Although tidal marsh and swamp habitat tree species commonly tolerate moderate salinities, they do not survive in high salinities. Salinity increases of several parts per thousand or more would likely change the distribution and potentially the amount, of tidal marsh and swamp habitat contributing woody debris to the estuarine habitat. This would potentially result in a short-term increase in woody debris at the expense of a long-term decrease in woody debris.

Riverine Reach

The riverine reach is a freshwater system, and no changes resulting from the Project are anticipated to introduce salinity to this reach. In addition, the anticipated change in water elevation is expected to be less than an inch, well less than the 19 inches necessary to cause an impact. Accordingly, no change to woody debris input is anticipated as a result of the proposed Project.

Estuary

Projected project-related changes to salinity are anticipated to be much less than the several parts per thousand needed to affect tidal marsh and swamp habitat (see Section 6.1.5, Salinity). In addition, the anticipated change in water elevation is expected to be less than 1 inch (see Section 6.1.7, Bathymetry), much less than the 19 inches that would be necessary to cause an impact. Accordingly, no change to woody debris input is anticipated as a result of the proposed Project.

River Mouth

Not applicable.

6.1.3.2 Conclusion

Changes in water level and salinity estimated for the proposed action are not estimated to be great enough to cause changes in the distribution or abundance of woody debris.

6.1.4 Turbidity (as related to Habitat-Forming Processes)

This section addresses turbidity as it relates to habitat-forming processes (see Section 6.1.36, Turbidity). Turbidity is discussed within the Habitat-Forming Processes Pathway because the ability of light to penetrate the river affects the amount of plant growth that can occur. This is important for habitat development, particularly in the shallow water areas, because the plant growth adds stability and reduces the chance for erosion.

Some temporary and localized changes to river turbidity levels are anticipated to occur from the Project at the location of dredging and disposal of dredged materials. These turbidity increases are not expected to be appreciably different in scope than the temporary turbidity increases associated with annual maintenance dredging, which would occur even without the deepening project. In addition to the potential effects from dredging and disposal activities, consideration is given in the following text to whether changes in ship wakes will occur that would lead to increased turbidity levels.

6.1.4.1 Increase in Turbidity Caused by Dredging Activities

There are three types of dredges, pipeline, hopper and mechanical, that will be used for project construction and maintenance. Each dredge has a slightly different effect on suspended sediment, and consequently on turbidity levels. The resuspension of sediment by each type of dredge and within each reach is explained in Section 6.1.1.1, Suspended Sediment Caused by Dredging Activities. The potential effects on turbidity are described below for each river reach.

Riverine Reach

Turbidity increases would be highest at the dredging location, but would be subject to mixing and related dilution by dispersive processes as it moves downstream. During construction, when two dredges may be operating in this reach, the total downstream suspended sediment increases are in the ranges of zero to 1 mg/L at 100,000 cfs and zero to 0.6 mg/L at 200,000 cfs (see Section 6.1.1.1, Suspended Sediment Caused by Dredging Activities). Based on the relationship between suspended sediment and turbidity shown in Figure 6-3, the resulting downstream turbidity increases would be on the scale of zero to 0.5 NTU and zero to 0.3 NTU for 100,000 cfs and 200,000 cfs, respectively. These increases are comparable to the natural variations in turbidity. The turbidity increases are transitory, existing only during actual dredging operations. The turbidity increases during maintenance dredging would be equal or less than those described here for construction.

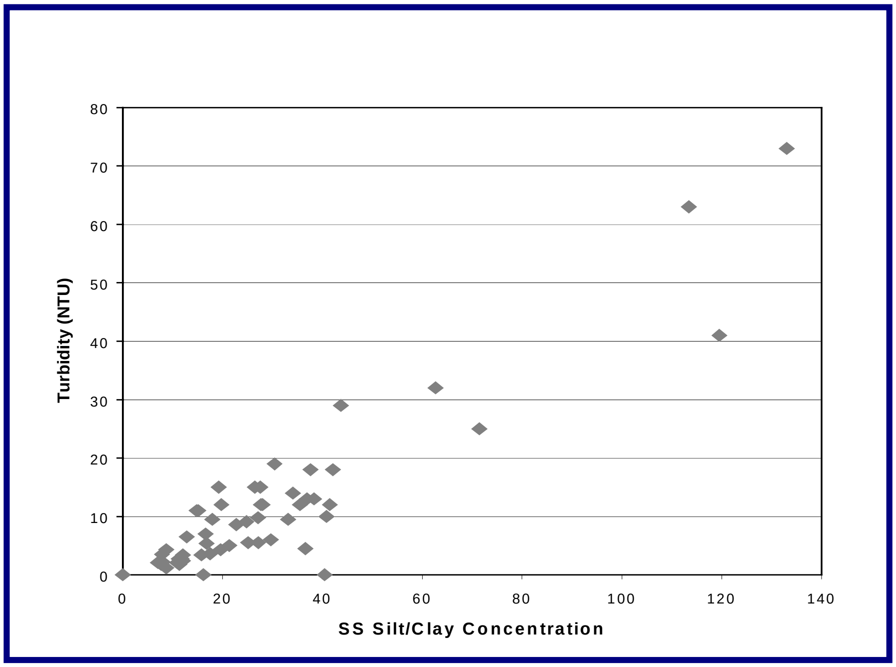


Figure 6-3: Relationship Between Turbidity and Suspended Silt and Clay in the Columbia River at Beaver, Oregon (RM 54)

Somewhat higher suspended sediment concentration increases (Section 6.1.1.1, Suspended Sediment Caused by Dredging Activities), and therefore turbidity increases, than those discussed above may occur if vessel berths at ports along the Columbia River are dredged to accommodate deeper-draft vessels. The material in these berths and slips may not be as sandy as that in the main channel; there may be more silts and clays. Any impacts from berth deepening would be short term, as the volume to be removed is relatively small.

Estuary

Construction and maintenance dredging in the estuary and the river upstream will influence turbidity in the estuary. As in the river, turbidity increases would be highest at the dredges and decrease as the plume moves downstream. Some turbidity measurements have been taken in the vicinity of an operating hopper dredge at RM 36. Those measurements found only 1 out of 22 readings above 10 NTUs.

During construction, two hopper dredges will be working in the estuary. After mixing, the combined turbidity increase from the two hopper dredges is expected to be less than 1 NTU. Most of this turbidity would be generated downstream of RM 25. The distribution within the estuary of the turbidity plume will depend on dredging location, river discharges, and ocean tides. Turbidity from upstream dredging would enter the estuary near RM 40 and be distributed throughout the estuary. The individual suspended particles causing increases in turbidity may remain in the estuary for up to 4 months. Local erosion and deposition, and mixing with ocean water, will continually change the turbidity levels. There is not likely to be any noticeable increase in turbidity in the ETM as a result of the dredging.

Turbidity increases from maintenance dredging will be similar to those during construction. The increase will depend on the number and location of dredges, but will generally be less than 1 NTU in the estuary.

River Mouth

No dredging activities associated with the Project will occur within the river mouth reach. The turbidity increases caused by upstream dredging will be discharged into the Columbia River plume.

6.1.4.2 Increase in Turbidity in Vicinity of Disposal Activities

As with the discussion of suspended sediments (see Section 6.1.1.2, Suspended Sediment Caused by Disposal Activities) caused by dredging activities, disposal activities at flowlane and ocean sites will temporarily increase turbidity when dredged material is released into the water column. Drainage water discharged from shoreline disposal sites will also contribute suspended sediments to the river causing localized turbidity increases at the disposal site outfalls.

Riverine Reach

Disposal activities will occur in many areas throughout the riverine reach. Most of the disposal will be upland, but some flowlane disposal is likely and shoreline disposal will occur at Sand Island. The turbidity increases will be the result of the suspended sediment increases described in Section 6.1.1.2, Suspended Sediment Caused by Disposal Activities. Return water from upland disposal sites will be held in settling ponds until it meets applicable Oregon or Washington water quality standards at an appropriate point of compliance after dilution for suspended sediment.

Shoreline disposal can generate elevated turbidity in the vicinity of the disposal site. The Corps measured turbidity near a shoreline disposal site at RM 24. Levels ranged from 9 to 20 NTUs in the disposal plume (within 50 feet of shore), compared to background measurements of 5 NTUs. At the mouth of the discharge pipe, turbidity reached 26 NTUs. These turbidity levels are substantially lower than levels of concern identified in Section 4.1.1. Dredging and shoreline disposal would generate a combined total of less than 1 NTU of additional turbidity, after mixing, and would only occur every 3 to 4 years at Sand Island.

Hopper dredging and flowlane disposal would create a fluctuating amount of turbidity increase due to the cycle of dredging, transport, and disposal. The turbidity increase from one hopper dredge would average less than 1 NTU, but levels could be higher in the disposal discharge plume and would be zero during transit periods (Eriksen, SEI Presentation, 2001).

Estuary

The turbidity increases in the estuary will be the result of the suspended sediment increases described in Section 6.1.1.2, Suspended Sediment Caused by Disposal Activities. There will be no upland or shoreline disposal in the estuary during construction.

The turbidity increases from upland disposal at Welsh, Pillar Rock, and Rice Islands will be very small because of the use of settling ponds at upland disposal sites during maintenance. Return water from upland disposal sites will be held in settling ponds until it meets applicable Oregon or Washington water quality standards at an appropriate point of compliance after dilution for suspended sediment.

Turbidity from shoreline disposal at Skamokawa and Miller Sands will be similar to that described for Sand Island. Shoreline disposal will only occur during maintenance dredging.

During construction, flowlane disposal would occur between RM 30 and 40. During maintenance dredging, flowlane disposal may occur anywhere along the channel in the estuary. Flowlane disposal will generate an average increase in turbidity of less than 1 NTU, but levels will vary as explained above. The location of flowlane disposal sites will cause most of the increased turbidity from those sources to be dispersed in the open portion of the estuary, downstream of RM 23.

Turbidity from the riverine reach could be distributed throughout the estuary, including the Cathlamet Bay area.

River Mouth

This reach will be affected by disposal at the ocean site and by increases in turbidity caused by the upstream dredging and disposal. The increases from upstream for both construction and maintenance dredging would be the same as those described for the estuary.

Ocean disposal will result in the release of discrete sediment plumes with an unknown level of turbidity. The individual plumes will drift with the ocean currents and eventually disperse. The rate at which the plumes disperse will depend on several factors, including river discharge, tide, ocean currents, ocean upwelling, wave size and direction, winds, and disposal location.

6.1.4.3 Ship Wakes

Riverine Reach

The potential change to ship wakes is not expected to be measurable; consequently, no resulting changes in suspended sediment are expected (see Section 6.1.1.3, Suspended Sediment Caused by Ship Wakes). In addition, no related change in turbidity is expected.

Estuary

There are no anticipated changes in estuarine shoreline erosion or suspended sediment related to ship wakes or hydrodynamics (see Section 6.1.1.3, Suspended Sediment Caused by Ship Wakes). Therefore, there would be no change in turbidity.

River Mouth

See Estuary, above.

6.1.4.4 Conclusion

Localized turbidity levels of 5 to 26 NTUs that might be caused by the proposed action are not likely to produce detectable effects on plant growth in the lower river. Not only is the amount of increase too low, but it will be localized to areas where dredging and disposal will occur, which does not include shallow water areas. In addition, the combined background and project-related turbidity concentrations are well below known salmonid impact levels. Turbidity as high as 400 NTUs is commonly found in river systems and estuaries where salmonids are produced (see Section 4.1.1).

There should be no change to turbidity from ship wakes.

Riverine Reach

In riverine areas where neither dredging nor disposal is occurring, there should be no observable increase in turbidity levels. In areas where dredging and disposal activities occur, there may be noticeable, short-term increases in turbidity near hopper dredges and shoreline disposal sites. Dredging operations (dredging and disposal combined) are likely to cause downstream turbidity increases of zero to 1 NTU, depending on the number and type of dredges operating.

Estuary

See Riverine Reach, above.

River Mouth

Upstream dredging and disposal operations will cause a turbidity increase of zero to 1 NTU, depending on the number and type of dredges operating. Ocean disposal will result in the release of discrete sediment (turbidity) plumes that will slowly disperse. There should be no change to turbidity from ship wakes.

6.1.5 Salinity

Salinity is an important indicator in assessing the successful adaptation and outmigration of juvenile salmonids in the lower Columbia River. The concentration of salinity in important habitat and rearing areas of the system and the longitudinal gradient of salinity between the freshwater and ocean environments that bound the estuary portion of the system are particularly important. The location of the ETM, which is an important location of nutrients in the system, is driven by tidal forcing processes that influence salinity intrusion. For these reasons, it is important to determine the extent to which channel deepening actions might change the salinity profile in the action area. This section describes the results of hydrodynamic/salinity models used to make this determination. See Appendices F and G for additional salinity modeling results.

6.1.5.1 Changes to Salinity Intrusion

Riverine Reach

Salinity intrusion does not extend upstream to RM 40, which is the division between the riverine reach and the estuarine reach. Consequently, salinity is not applicable in the riverine reach.

Estuary

The salinity profile in the estuary is governed by two opposing processes: freshwater outflow and ocean tidal inflow. The potential effect on salinity as a result of dredging actions taken to deepen the navigation channel will, therefore, come from alteration of the river/estuary cross-sectional area. The alteration of bathymetry through the dredging of the navigational channel in the estuary portion of the system (RM 3 to 40) is the area of concern with regard to potential effects on salinity gradients.

Two models have been applied to the system to assess the impact of the proposed channel deepening on salinity in the system: the Corps of Engineers – Waterways Experiment Station (WES) applied the RMA-10 model and OHSU/OGI applied the ELCIRC (Eulerian – Lagrangian CIRCulation) model as part of their CORIE system. A description of the models and presentation of all model results are provided in Appendices F and G.

Based on the WES RMA-10 modeling, the largest impacts on salinity profiles occur at the lowest river flow analyzed (70,000 cfs). For this base versus plan comparison, the model predicts that deepening the channel would increase salinity by 0.1 to 0.15 ppt in shallow areas of the estuary. In particular, this range of increase shows up in Cathlamet Bay and Grays Bay. Salinity increases in the range of 1.0 to 1.5 ppt are also predicted to occur at the bottom of the navigation channel in the vicinity of Tongue Point and back through the Miller Sands channel.

The OHSU/OGI application of ELCIRC for the base versus plan model comparison was conducted as an independent check on the WES RMA-10 modeling. In addition, OHSU/OGI used their results to determine if the plan would be expected to cause a significant change in habitat opportunity as defined by Bottom, et al. (2001) and the SEI workshop process. The low-flow results of the ELCIRC model are for a base versus plan comparison for what OHSU/OGI calls salinity “accumulation” (depth- and time-averaged salinity over the course of the weeklong run). This confirms that the largest salinity changes would occur in the navigation channel and that salinity changes in Cathlamet Bay and Grays Bay will be small (less than 0.25 ppt). Most changes in the navigation channel were similar to those predicted by RMA-10 (about 1 ppt), but those around RM 8 to 10 were somewhat higher (in the range of 3 to 5 ppt). The ELCIRC model also predicted a slight (less than 1 ppt) decrease in salinity in the shallow water areas of the central estuary. But it does indicate that larger increases in salinity than those predicted by RMA-10 might occur in Youngs Bay and along the Oregon side of the navigation channel up to Tongue Point. In Youngs Bay, the ELCIRC model predicted salinity increases of -0.5 to 1.0 ppt above the base condition salinity of 7 to 23 ppt and zero to 3 ppt increases to base salinity of 17 to 34 ppt. The base salinity in Youngs Bay is highly variable because of the Bay's bathymetry and freshwater inflows.

When the ELCIRC results were used to compute habitat opportunity based on the salinity criterion of zero to 5 ppt, it was determined that in Cathlamet Bay there was virtually no difference in the hours per week for the base and plan. Habitat opportunity based on salinity was always between 145 and 150 hours per week, regardless of whether base or plan bathymetry was used and regardless of the base flow condition used. These results suggest that channel deepening will have no significant impact on salinity intrusion.

River Mouth

Salinity changes in the river mouth are predicted by both models to be near zero.

6.1.5.2 Altered Location of ETM

The estuary is the location where saltwater and freshwater are mixed. In the Columbia, as in most river-dominated estuaries, tidal processes and river flow results in a zone of increased turbidity, the ETM. The turbidity in the ETM is the combination of both the concentration of suspended organic matter and the resuspension of organic and inorganic matter from the bottom. The length of the ETM is typically 0.6 to 3 miles. The position of the ETM ranges between RM 9 and 18 from Youngs Bay to Tongue Point (Simenstad, 1994). This section looks at the effect of the Project on the ETM.

Riverine Reach

As shown in Figure 6-4, the mean of the ETM fluctuates from approximately RM 9 to 18 (Simenstad, 1994). Therefore, there are no effects associated with alteration of the location of the ETM in the riverine reach.

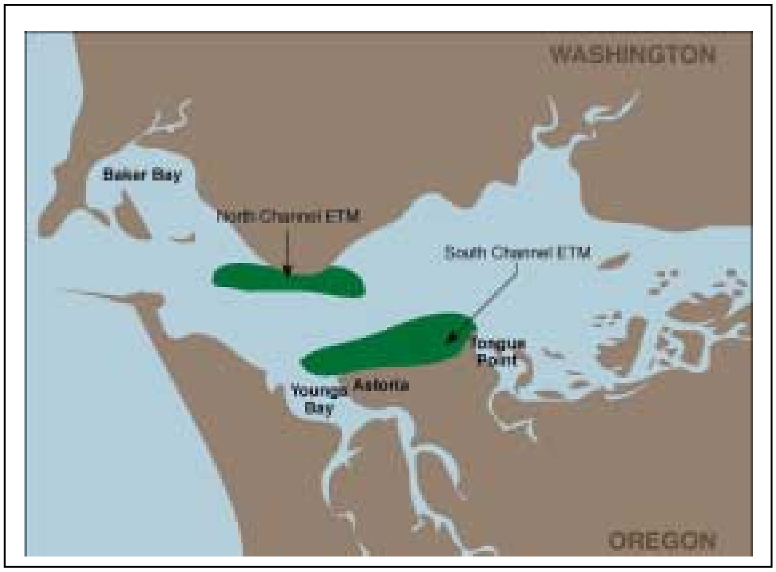


Figure 6-4: Location of the ETM

Estuary

The ETM is an important zone of organic matter accumulation and cycling. A change in the location range of the ETM may affect the distribution of nutrients and thereby the location and abundance of salmonid food in shallow water habitats.

The position of the turbidity maximum appears to be associated with the tide and river currents that control salinity intrusion. The turbidity maximum in the Columbia River estuary currently fluctuates up to 9 miles each day between RM 9 and 18 (Simenstad, 1994). Its range depends on the river discharge and tidal conditions as shown in Figure 6-5. According to the RMA-10 modeling results, with the deeper navigation channel the limit of salinity intrusion could move upstream about a mile for any given discharge. To the extent that the ETM is related to salinity intrusion, this may result in an upstream shift of up to 1 mile in the upstream and downstream limits of the ETM.

The potential shift of the ETM would occur in a relatively small part of the estuary as demonstrated in Figure 6-4. It would generally remain within the current range or path of the ETM, with a small shift in the upstream and downstream boundaries. In addition, it would be smaller than the existing daily fluctuations caused by flow conditions. The effect of the potential shift of the ETM on distribution of nutrients in the estuary is expected to be so small that it cannot be measured. The ETM suspends nutrients in the estuary, which are then distributed by tides and currents in the river system. Any fluctuation in the location of the ETM that may result from the Project is not expected to affect the tidal influences and currents that distribute nutrients throughout the estuary. Further, salmonids do not feed in the area occupied by the ETM; rather, salmonids benefit from the distribution of nutrients out of the ETM throughout the estuary. These are the nutrients that are used as food by the organisms on which juvenile salmonids prey in shallow water habitats.

River Mouth

The ETM occurs only in the estuary. Therefore, no effects are associated with alteration of the ETM location in the river mouth reach.

Figure 6-5: Characteristic Estuarine Turbidity Maximum (ETM) Variations Under "Three Scenarios" in the Columbia River Estuary

6.1.5.3 Conclusion

Based on modeling results, the proposed actions will have little to no impact on salinity intrusion. The Corps is proposing to verify this conclusion through a monitoring survey of habitat conditions before, during and after completion of the Project (see Section 7).

Riverine Reach

No changes to salinity are expected to occur in the riverine reach because the ETM does not extend into this reach.

Estuary

Based on modeling results, the proposed actions will have little to no impact on salinity intrusion:

- Salinity increases of less than 0.5 ppt in the shallow embayments of the estuary (e.g., Cathlamet Bay, Grays Bay). Salinity increases up to 5 ppt would occur in areas not used by juvenile salmonids (bottom of the navigation channel).

- No measurable difference in habitat opportunity is anticipated, based on the modeling results.

The computed differences between base and plan for salinity in shallow areas are much smaller than natural temporal variations due to normal variations in freshwater flow and tidal dynamics.

Likewise, the potential upstream shift of the ETM of less than a mile will have an insignificant effect on the distribution of nutrients in the estuary and, therefore, on salmonids.

River Mouth

No changes to salinity caused by the proposed action are expected to occur in the river mouth reach.

6.1.6 Accretion/Erosion

Some anticipated changes in accretion/erosion due to the proposed channel improvement project include shoal formation (accretion) and shoreline erosion. Following deepening of the channel, accretion will occur in the navigation channel for some time as the riverbed adjusts (stabilizes) to the new depth via side-slope adjustment. Gradual bank erosion in sandy beach nourishment sites may also occur for some time, in response to the side-slope adjustment. These effects are addressed in Sections 6.1.2, Bedload, and 6.1.7, Bathymetry.

Riverine Reach

Riverbed side-slope adjustments and some shoreline erosion will alter the accretion and erosion patterns within this reach. Those effects are addressed in Sections 6.1.2, Bedload, and 6.1.7, Bathymetry. The alteration of the accretion and erosion patterns will not affect suspended sediment or bedload transport rates (see Sections 6.1.1, Suspended Sediment and 6.1.2, Bedload). The slight increases in suspended fine sediments during dredging and disposal operations will not increase accretion in the riverine reach because the river will transport those sediments to the estuary.

Estuary

The estuary is the area most likely to undergo changes in accretion due to the proposed Project. Accretion/erosion in the estuary could be altered by side-slope adjustments along the navigation channel, or by changes in river hydraulics or sediment supply. The project is more likely to increase accretion than to increase erosion.

The potential side-slope adjustments are limited to the Miller Sands area, and those effects are addressed in Sections 6.1.2, Bedload, and 6.1.7, Bathymetry. There could be resulting minor changes in accretion/erosion at this location.

The changes in river hydraulics are very small (see Sections 6.1.7, Bathymetry and 6.1.6, Accretion/Erosion) and are not likely to change accretion or erosion in the estuary.

Accretion in the estuary is influenced by the amount and type of sediment being delivered from upstream. This is reflected in the estimated reduction in the amount of flow and estuary accretion from 2 to 5 mm per year before flow regulation to about 1 mm per year after flow regulation (see Section 2). The deepening project will cause small increases in fine-grained suspended sediment delivered to the estuary during dredging and disposal operations (see Sections 6.1.1.1, Suspended Sediment Caused by Dredging Activities and 6.1.1.2, Suspended Sediment Caused by Disposal Activities). Based on the resuspension of less than 200,000 cubic yards (fine material makes up less than 1 percent of the total volume to be dredged), a fine material deposition rate of 30 percent (Hubbell and Glenn, 1973), and a uniform distribution of deposition throughout the 95,500 acres of open water in the estuary, there would be an average of about 0.1 mm per year of additional accretion during construction. The natural background deposition during that 2-year period would be around 2 mm per year.

Over the long term, the Project will have little effect on accretion in the estuary. There will be slightly more suspended fine sediment as a result of maintenance dredging and disposal. Over 20 years, this could result in less than 0.1 mm of estuary deposition above what would be caused by maintaining the existing channel. An upstream shift in the ETM may cause a minor change in accretion patterns, but the long-term effects are not expected to be detectable.

Sandy sediment within the river channel is one potential source of material for habitat-forming accretion in the estuary. During the reconsultation process, discussion and analysis focused on the potential long-term effects on accretion of removing sand from the upstream channel. The concern was that removing sediment would reduce the source of the estuary's sediment supply . However, as explained in Sections 6.1.1, Suspended Sediment, and 6.1.2, Bedload, the removal of sand from the river will not alter sediment transport to the estuary. The volume to be dredged over the life of the project is only a tiny fraction of the total volume of sand in the riverbed. In addition, transport potential, rather than sand supply, is the limiting factor in sediment supply to the estuary. Also, sediment inflow to the dredging area from upstream of Vancouver is essentially the same as the sediment transport at RM 54, indicating the main material source is upstream of the project.

The above predicted changes in accretion are all the results of very slight project-related changes in suspended sediment concentrations. The effects are thus dispersed throughout the estuary by the distribution of flows. The naturally occurring local accretion and/or erosion rates are influenced by site specific hydraulics and can be much greater than regional rates caused by the deposition of suspended sediment. As an example, Eriksen (SEI Presentation, 2001) found the north channel between RM 5 and 7 had infilled up to 20 feet between 1982 and 2000. Natural accretion and erosion will continue on this scale in the estuary and will likely dwarf any project-related changes.

River Mouth

The Project is not anticipated to have an effect on accretion or erosion at the river mouth.

6.1.6.1 Conclusion

Riverine Reach

Riverbed side-slope adjustments and some shoreline erosion will alter the accretion and erosion patterns within this reach.

Estuary

The Corps believes that the amount of material to be removed from the system is such a small proportion of the total available sand within the system that there is no potential for a discernible effect on estuary accretion.

River Mouth

No changes to accretion/erosion are expected in this reach.

6.1.7 Bathymetry (as Related to Bottom Elevation Contours and Water Surface)

Bathymetric changes will result from the Project. First, dredging will immediately lower the riverbed at the dredge site and lead to long-term changes to the adjacent side slopes. Effects of side-slope adjustment are addressed in Section 6.1.2.1, Potential Reduction in Volume of Bedload Caused by Removal of Channel Materials. Second, in-water and shoreline disposal will raise bed elevations at the disposal site. The disposal material will then be incorporated into the riverbed, forming sand waves and gradually moving downstream, mainly as bedload transport (see Section 6.1.2.2, Potential Effects to Salmonid Habitat Caused by Side-Slope Adjustment). Third, the deeper navigation channel will cause a slight effect on water surface elevations. This could result in a change in water depth. These three potential effects are addressed below.

6.1.7.1 Bathymetric Changes from Dredging

Immediate lowering of the channel will occur where dredging occurs. This is not expected to affect salmonid habitat (see Section 6.1.10, Water Column Habitat).

Riverine Reach

Dredging will lower the riverbed by up to 3 feet in those areas shown in Figures 3-4 to 3-7 of this BA. The exact amount of riverbed lowering and the final dredging locations will depend on river bathymetry just prior to construction. There will be no changes in bathymetry in the approximately 40 percent of the navigation channel in this reach that will not require dredging.

Estuary

Dredging will lower the riverbed by up to 3 feet in those areas shown in Figures 3-8 and 3-9 of this BA. The exact amount of riverbed lowering and the final dredging locations will depend on river bathymetry just prior to construction. There will be no changes in bathymetry in the approximately 55 percent of the navigation channel in this reach that will not require dredging.

River Mouth

No changes to bathymetry are anticipated to occur within this reach.

6.1.7.2 Bathymetric Changes from Disposal

In-water and shoreline disposal will raise elevations at disposal sites. The disposal material will then be incorporated into the riverbed and gradually move downstream as bedload transport (see Section 6.1.2.2, Potential Effects to Salmonid Habitat Caused by Side-Slope Adjustment).

Riverine Reach

Shoreline disposal at Sand Island (O-86.2) will periodically alter the bathymetry of the site. Disposal will raise the riverbed of shallow water areas along the beach. Some areas could change from shallow water to beaches. The disposal will erode away in 3 to 4 years and then the areas will be filled again by disposal.

Flowlane disposal will raise the riverbed intermittently along the channel throughout the life of the project. Flowlane disposal will generally be in portions of the river in or near the navigation channel that are between elevations -50 and -65 feet CRD. The sand will be spread out during disposal by keeping hopper dredges moving as they dump and by frequently moving the discharge pipe from a pipeline dredge. The disposal material will then be incorporated into the riverbed, forming sand waves and gradually moving downstream, mainly as bedload transport. Flowlane disposal is expected to be about 0.5 mcy during construction and 0.5 to 1.0 mcy per year over the first 20 years of maintenance.

Estuary

Shoreline disposal at Skamokawa (W-33.4) and Miller Sands (O-23.5) will cause bathymetric changes similar to those described for Sand Island.

Disposal is expected to occur periodically at Skamokawa and annually on at least part of Miller Sands.

The bathymetric changes caused by flowlane disposal in the estuary will be similar to those described for the riverine reach. The annual flowlane disposal volumes are expected to begin at about 1 mcy per year and decline to about 0.7 mcy per year in 20 years.

River Mouth

No changes to bathymetry are anticipated to occur within the entrance. Ocean disposal will create mounds in the deep water disposal site that are not expected to change.

6.1.7.3 Changes in Water Surface Elevation Resulting from Hydrodynamic Changes

The changes in channel geometry from dredging and disposal may affect the flow of water in the lower Columbia River. As a result, water surface elevation and water depth may change in response to deepening of the navigation channel. These potential effects on river hydrodynamics may occur throughout the river system below Bonneville Dam; however, since the proposed changes in channel geometry are small relative to the current depth and width of the river, the magnitude of this effect on water depth is not expected to be significant. Numerical models discussed below are used to assess these potential changes in water depth.

Riverine Reach

There are no predicted changes in water surface elevations downstream of RM 80 as a result of the Project. Modeling predicts water surface reductions would begin near RM 80 and become progressively larger in the upstream direction. The decreases would be in the range of 0.12 to 0.15 feet at RM 106. These reductions would be caused by removal of sediments in the riverine reach of the navigation channel. This change is not expected to have a discernible impact in this area.

Estuary

The WES RMA-10 model indicates that the impact of channel deepening on surface water elevation is minimal. Differences between base and plan are estimated to be between -0.02 foot and 0.02 foot for all locations between the mouth and the upper estuary (Puget Island).

Modeling conducted by OHSU/OGI supports the results of the WES model. The OHSU/OGI model presents elevation differences in terms of hours of habitat opportunity. Habitat opportunity, as defined by Bottom, et al. (2001), considers water depth and velocity conditions that provide favorable habitat for juvenile salmonids. In terms of water depth, habitat opportunity is defined as shallow environments between 10 centimeters and 2 meters (about 0.5 to 6 feet). Using this definition of habitat opportunity, Table 6-1 lists the average number of hours in which the depth criterion is met (over a 168-hour week) for Cathlamet Bay. Results are shown for five 1-week model simulations spanning a range of flow conditions. The area-weighted averages are nearly identical for base and plan, indicating that the proposed actions will not have an impact on habitat opportunity as it relates to water depth.

Table 6-1. Area-weighted Average Habitat Opportunity Hours – Elevation, Cathlamet Bay

Model Period	Approximate Flow Range (10^3 cfs)	Base (hr)[1]	Plan (hr)[1]
July 01-week 27	70 – 150	45.0	45.0
July 01-week 28	70 – 110	49.4	49.3
May 01-week 18	130 – 165	45.8	45.6
May 01-week 19	70 – 165	43.5	43.5
May 97-week 18	360 – 500	44.5	44.4

[1] Area-weighted average number of hours meeting habitat opportunity criteria over a 168-hour model run.
Source: Baptista, SEI Presentation, 2001b.

River Mouth

No changes to water surface elevations are anticipated in this reach.

6.1.7.4 Conclusion

Bathymetric changes related to the proposed actions include those caused by dredging and disposal. In addition, water surface elevations could change because of deepening the channel. The Corps is proposing to verify this conclusion through a monitoring survey of habitat conditions before, during, and after completion of the Project (see Section 7).

Riverine Reach

Bathymetric changes will include up to 3 feet of deepening in areas of the navigation channel that are currently shallower than -48 ft CRD and some rise in the riverbed at shoreline and flowlane disposal sites. In addition, there is a potential for up to 3 feet of deepening along the side slopes adjacent to the dredge cuts (see Section 6.1.2.1, Potential Reduction in Volume of Bedload Caused by Removal of Channel Materials). Water surface elevation could be affected between RM 80 and 146. The decrease could be up to 0.18 feet (approximately 2 inches) at the upstream end of the project.

Estuary

Bathymetric changes will include up to 3 feet of deepening in areas of the navigation channel that are currently shallower than -48 ft CRD and some rise in the riverbed at shoreline and flowlane disposal sites. In addition, there is a potential for zero to3 feet of deepening along the side-slopes adjacent to the dredge cuts (see Section 6.1.2.1). Water surface elevation is not affected in the estuary by the proposed actions.

River Mouth

No changes to bathymetry are anticipated from the Project in the entrance. Ocean disposal will create mounds in the deep water site that are not expected to change.

6.1.8 Tidal Marsh and Swamp Habitat

Juveniles of each of the 14 listed salmonids and coho (candidate species) may potentially use tidal marsh and swamp habitat, but ocean-type chinook and chum salmon and cutthroat trout are more likely to commonly use the habitat. The results of numerical salinity changes models (see Section 6.1.5, Salinity), a review of salinity tolerances and ranges of marsh species, and data on elevation ranges occupied by these habitats indicate that the Project will have minimal effects on tidal marsh and swamp habitat.

6.1.8.1 Effect on Tidal Marsh and Swamp Habitat

Deepening the lower Columbia River channel is not likely to directly change the amount or character of tidal marsh and swamp habitat. No dredging within the tidal marsh and swamp habitat or filling of tidal marsh and swamp habitat is proposed as a part of the Project.

Riverine Reach

The Project may lower the river surface elevation by up to 0.18 foot at Bonneville Dam and then decreasing downriver to no change at RM 80 (see Section 6.1.7, Bathymetry) and change salinity levels in the lower Columbia River as discussed in Section 6.1.5, Salinity. At the upstream end of the project area (Bonneville Dam to Vancouver), the daily tidal fluctuation between high and low tides is approximately 1.5 feet to 2.5 feet. Flow regulation at the mainstem dams above the action area can significantly increase this daily fluctuation. Lower water level would allow marsh progradation (i.e., building out) waterward of the marsh. Modeled changes in water levels of an inch or less may produce changes in tidally influenced marsh and swamp areas, but the changes are likely to be too small to detect.

Tidal marsh and swamp habitat occurs sporadically along the margins of shallow water areas of the Columbia River from Vancouver down to the estuary, which are scattered throughout the action area. There is also substantial marsh and swamp habitat in rivers and stream tributaries to the mainstem of the Columbia River. However, most tend to be concentrated in the estuary and downstream portions of the riverine reach. Although progradation could occur within the tidal marsh and swamp areas within this reach, no predicted increase or decrease in tidal marsh and swamp habitat is expected as a result of the proposed Project. Areas where gradual shoreline erosion could be expected to occur are RM 99, 86.2, 75, 72, and 46 to 42 (see Section 6.1.2, Bedload). These areas do not contain shoreline tidal marsh or swamp habitat.

Estuary

Water level changes will not significantly change with the Project in the estuary. Water levels within the tidally influenced area of the estuary commonly vary from 4 to 12 feet twice each day as the result of tides, varying between neap and spring tide periods. Neap tides are periods of minimum difference between sequential high and low tides. Spring tides are periods of maximum difference between sequential high and low tides.

During the course of reconsultation, consideration was given to whether changes in salinity resulting from the Project could potentially affect tidal marsh and swamps. In particular, the potential for a salinity shift to cause shifts in the location of aquatic conditions that support existing vegetation within tidal marsh and swamp habitat was examined.

Baseline, pre-project salinity conditions within the estuary vary daily with tide condition and seasonally with changes in river discharge. Daily changes at specific locations can vary from low salinities of less than 1 ppt to as high as 15 to 20 ppt. Modeling (see Section 6.1.5, Salinity) indicates a post-project increase in salinity of from 0.1 to 0.15 ppt in shallow areas of the estuary, such as Cathlamet and Grays Bays. These two bays contain the vast majority of tidal marsh and swamp habitat within the action area.

A literature review of salinity tolerances and ranges of tidal marsh and swamp species showed that most of the dominant species in the estuary adapted for some salinity can tolerate relatively wide variation in salinity (Hutchinson, 1989; Corps, 1999a). For example, Macdonald (1984) found that the sedge (*Carex lyngbyei*) and bent grass (*Agrostis alba*) occurred over a salinity range of zero to 16 ppt. Even predominantly freshwater species, such as American waterplantain (*Alisma Plantago-aquatica*) and spike rush (*Eleocharis* spp.) can tolerate salinity ranges of zero to 4 ppt and zero to 3 ppt, respectively. This literature review and the results of the modeling suggest that it is unlikely that the Project will result in a measurable change in the species distribution of the dominant marsh and swamp assemblages within the estuary. In addition, the potential for an effect is further reduced because the extent of salinity distribution within the action area is unlikely to change within the shallow water areas where much of the tidal marsh and swamp habitat is located.

River Mouth

Not applicable.

6.1.8.2 Conclusion

The structure, distribution, net productivity, and detritus production of marshes and swamps in the action area will not be directly affected by the Project. Based on modeling results, the major habitat-forming processes of bathymetry and salinity are predicted to be affected in a minor way by the Project. The amount or characteristics of tidal marsh and swamp habitat along the shallow water margins of the lower Columbia River are not expected to be significantly affected by salinity or water elevation changes associated with the Project. The Corps is proposing to verify this conclusion through a monitoring survey of habitat conditions before, during, and after completion of the project (see Section 7).

6.1.9 Shallow Water and Flats Habitat

Shallow water and flats habitats, provide, important feeding and rearing areas for outmigrating juvenile salmonids, especially ocean-type chinook salmon (Snake River fall chinook, lower Columbia River fall chinook), chum salmon, and cutthroat trout. Some individual juveniles of each of the other listed salmonids and coho may potentially use shallow water and flats habitat within the lower Columbia River, but they are more likely to be in open water away from the shallow shorelines. In addition, adult chum salmon use shallow water habitat for spawning in the riverine reach. These sites are all above the Interstate 5 Bridge at Vancouver, Washington (Howard Schaller, pers. comm., 2001). They are located near Bonneville Dam and the city of Vancouver. No other spawning occurs in the action area by this or other salmonid populations.

The Project could affect shallow water and flats habitat in several potential ways. First, side-slope adjustments associated with channel deepening may cause a shift in the location of shallow water habitats associated with past beach nourishment sites. This potential effect is discussed in Section 6.1.2, Bedload. Second, shoreline disposal for beach nourishment will result in the placement of dredge materials in shallow water habitats at three locations. Third, changes in water surface elevation have been evaluated to determine whether a potential exists for habitat opportunity to be reduced within shallow water areas. This effect is discussed in Section 6.1.7, Bathymetry. Effects on salmonid spawning habitat by changing surface elevations are discussed below.

6.1.9.1 Shoreline Disposal in Shallow Water and Flats Habitat

Shoreline disposal for beach nourishment is proposed for three sites within the action area. Shoreline disposal involves discharge of dredged materials from a discharge pipe that is placed on the beach and then moved slowly into the shallow shoreline areas until they are converted to upland. During reconsultation, discussions regarding shoreline disposal have focused on the potential for disturbing salmonids that use existing shallow water habitat within these areas. None of the proposed sites will provide additional habitat for avian predators that prey on juvenile salmonids, such as Caspian terns.

Shallow water areas at discrete locations will be affected by shoreline disposal. The shoreline disposal locations have steep side slopes (around 10 percent) that provide about 7 acres per mile of shallow water areas. Shoreline disposal will affect a total of about 4.5 miles or 30 acres of shallow water areas. However, the three disposal sites are all highly erosive and do not contain many of the important habitat features that shallow water habitats typically include, such as low velocity, vegetation, and food sources. These sites had previously been approved by NMFS for shoreline disposal because of their low productivity. Side-slope adjustment will occur over a period of 5 to 10 years. This process will cause shallow water and flats habitat at six historical shoreline disposal sites to migrate laterally; however, the quantity and quality of shallow water and flats habitat is expected to remain constant.

Riverine Reach

One shoreline disposal site is located within the riverine reach at Sand Island (O-86.2). The site is a beach nourishment site intended for disposal during both construction and maintenance dredging. The site is intended to provide recreational benefits, as well as to protect existing riparian habitat. A narrow band of shallow water will be affected by disposal at the Sand Island (O-86.2) shoreline disposal site. This site is highly erosive and does not provide any salmonid habitat. This site has been previously approved for shoreline disposal by NMFS because of its low productivity (Hinton and Emmett, 1994).

Estuary

Miller Sands Island, which is located within the estuary at O-23.5, is a beneficial use site that will provide long-term benefits by maintaining the existing embayment for salmonid habitat. The site is intended for use during maintenance dredging. The shoreline disposal site at Miller Sands is along the channel side of the island and affects a narrow band of shallow water along the shore. The site is highly erosive and provides little shallow water or juvenile salmonids rearing habitat. This site has been previously approved for shoreline disposal by NMFS because of its low productivity.

Skamokawa Beach, which is located at W-33.4, is a beneficial use site intended to enhance the public beach as well as provide sand for sale for other uses. The site is used for maintenance dredging, but only periodically. The shoreline disposal site at Skamokawa Beach affects a narrow band of shallow water along the shore. The site is highly erosive and provides little shallow water or juvenile salmonids rearing habitat. This site has been previously approved for shoreline disposal by NMFS because of its low productivity (Hinton and Emmett, 1994).

River Mouth

No shoreline disposal is planned for the river mouth and no changes in shallow water habitat are anticipated.

6.1.9.2 Potential Effect on Salmonid Spawning Activity and Spawning Habitat

Section 6.1.7, Bathymetry, describes a potential decrease in water surface elevation of up to 0.18 foot. The potential lowering would occur between RM 80 and 146. This magnitude of surface elevation change on salmonid redds (spawning nests) in the mainstem of the Columbia River (action area) would have no effect on adult spawning or survival of eggs in redds. The location of spawning and redds is in water depths of several feet and areas that water elevations fluctuate several feet each day.

Riverine Reach

There are two areas of known salmonid spawning in this reach; adult chum salmon spawn near Bonneville Dam and by the Interstate 205 bridge near some under waterspring seeps in the vicinity of Vancouver, Washington. The proposed actions will have no effect on spawning activity or habitat.

Estuary

No salmonid spawning occurs in this reach.

River Mouth

No salmonid spawning occurs in this reach.

6.1.9.3 Conclusion

There is little potential to disturb salmonids that use shallow water habitats at the three shoreline disposal sites. None of the sites offers the conditions that provide salmonid habitat because the shallows at all three sites have high velocity currents and relatively rapid erosion. These currents are likely to prevent benthic invertebrate populations from establishing and young salmonids from rearing in these areas. As with tidal marsh and swamps habitat, the Corps is proposing to verify any impacts to shallow water areas that may occur through a monitoring survey of habitat conditions subsequent to completion of the project (see Section 7).

Limited chum salmon spawning occurs in the project action area above the Interstate 5 bridge at Vancouver, Washington. The proposed action will not affect spawning activities or habitat.

6.1.10 Water Column Habitat

The proposed Project may cause the following potential modifications to characteristics of the water column habitat. First, there is the potential for a slight shift in the upstream limit of the ETM. This issue has already been discussed in Section 6.1.5.2, Altered Location of ETM. Second, there is the potential for a slight shift in the upstream limit of salinity intrusion (See Section 6.1.5, Salinity). Third, proposed drilling and blasting activities have the potential to disturb water column habitat. Finally, the Corps is proposing to use a dredging schedule that is consistent with the existing BO for O&M dredging. Because these activities will occur in areas where salmonids are not present, at depths of greater than 20 feet, timing window recommendations for activities within the Columbia River do not apply (see Table 3-1).

6.1.10.1 Effects of Drilling and Blasting on Water Column Habitat

Riverine Reach

Blasting will be done during the preferred in-water work window. This is the period when salmonid abundance is lowest and will minimize impacts to the listed populations. In addition, because there may be some fish in the river, the blasting plan will be designed to further minimize any impacts by keeping over-pressures above the blast zone to less than 10 psi (Corps, 1999a). This level is generally believed to be below the level at which salmonids will be impacted. A state-approved plan for blasting will also be developed to further minimize impacts.

Estuary

No drilling and blasting is proposed within the estuary, and no effects are anticipated to the water column habitat within the estuary from drilling and blasting activities.

River Mouth

Not applicable.

6.1.10.2 Proposed Dredging Timelines

Riverine Reach

Dredging and disposal during construction will be done year-round for 2 years. Though this is outside of the normal November 1 to February 28 in-water work period for the lower Columbia River, it is not anticipated that it will have any major impact on listed salmonids. (See Table 3-1 for dredging timing.) Salmonids normally do not occur to any extent in the areas being dredged or the disposal sites (except the three shoreline sites). Juvenile salmonids normally migrate along the channel margins using the side slopes as structure. They occur primarily at depths less than 20 feet and so would not be expected to be impacted by dredging and disposal operations. Though juvenile salmonids can occur near the three shoreline sites, these sites are highly erosive and do not provide much, if any, habitat.

Estuary

See Riverine Reach, above.

River Mouth

No dredging will occur in the river mouth reach.

6.1.10.3 Conclusion

Based on the discussion, above it is unlikely that dredging and disposal year-round for 2 years will have any effect on listed salmon. This is primarily a result of the fact that salmonids do not occur in the deeper channel areas to any extent. Restricting blasting to the in-water work period, in conjunction with an approved blasting plan, will reduce or eliminate impacts to listed salmonids because this is the period when they are the least abundant.

6.1.11 Light

Light drives photosynthesis and ultimately the growth of plants. The most likely potential effect on light penetration comes from anticipated turbidity increases associated with dredging and disposal activities.

6.1.11.1 Reduction in Light from Increases in Turbidity

Riverine Reach

See Estuary, below.

Estuary

The amount of light reaching plankton and benthic macrophytes is a function of water clarity. Any action that reduces water clarity will reduce the amount of light reaching plants. The discussion of turbidity (see Section 6.1.4, Turbidity) summarizes the sources of increased turbidity and is highly relevant to the present discussion of light.

Short-term reductions in light could be associated with turbidity from dredging, flowlane disposal, dredged material disposal, and ship wakes. In Section 6.1.4, Turbidity, it was concluded that the transitory nature of dredging activity and the dilution effect of currents would allow turbidity associated with the Project to dissipate relatively rapidly in a given area (i.e., in less than an hour).

Localized turbidity levels of 5 to 26 NTUs (see Section 6.1.4, Turbidity) that might be caused by the proposed Project are not likely to produce detectable effects on plant growth in the lower Columbia River. Not only is the amount of increase too low (particularly given the short duration of the increase), but it will be localized to areas where dredging and disposal will occur (within a few hundred yards of the activity), which avoid shallow water areas.

River Mouth

See Estuary, above.

6.1.11.2 Conclusion

Light will be temporarily reduced in the water column where sediments are either stirred up or discharged by dredging and disposal activities. Information on the location and duration of dredging and disposal activities indicates that they will affect a very small but unquantified area relative to the entire wetted surface of the system. Given the transient and localized nature of the anticipated turbidity increases, it is unlikely that they will result in discernible effects to primary productivity within the action area.

6.1.12 Nutrients

A balance of nutrient input is important for the maintenance of a healthy river system. If nutrients, especially phosphate and nitrate, are in short supply within a system, it will limit the growth of plants. Conversely, if nutrients are overabundant (i.e., eutrophic), noxious blooms of algae and aquatic macrophytes can occur, which can have a negative effect on water and sediment quality. Nutrients are dissolved in water both in the water column itself and in sediment pores. They are also constantly being released through organic matter mineralization in the water and sediments. Zones of most intense remineralization in the Columbia River are associated with the ETM (Simenstad, 1994) and sediments. Nutrients can be released to the water column through disturbance of bottom sediments.

Nutrients in the Columbia River have not been evaluated sufficiently to develop nutrient level criteria. These criteria are used to define nutrient levels indicating a properly functioning system. Sullivan, et al. (2001), summarized data over a 1-year period (1995-1996) from a station at RM 53 and monthly averages over a 16-year period (1978-1994) from RM 141. The concentrations varied from a winter-spring high to a summer low, with all responding to typical patterns of nutrient use by phytoplankton during the spring-summer increase (Table 6-2). The winter increase in the river appears to be related to discharges from the dams. Nutrient concentrations do not appear to be causing algal blooms or other problems and can be used as the best estimate of proper function for the current system. Even if sufficient nutrients were added to the system to cause an algal bloom, the flow rates and currents within the river and estuary would prevent such a bloom.

Table 6-2: Nutrient Concentrations[1] at USGS Stations at RM 53 and RM 141

Nutrient	Season	Concentration (µmol) at Station RM 53	Concentration (µmol) at Station RM 141
Nitrate + Nitrite	Winter	30	25
	Summer	6	5
Phosphate	Winter	0.70	0.80
	Summer	0.10	0.40
Silicate	Winter	220	180
	Summer	125	120

1 Concentrations are approximate values for the period of greatest to least concentrations in winter and summer, respectively.

Source: Summarized from Sullivan, et al., 2001.

6.1.12.1 Increase/Decrease in Nutrients

Riverine Reach

See Estuary, below.

Estuary

Suspending sediments, particularly those that may have higher organic matter content, will release inorganic nutrients into the water column. For example, dredging and flowlane disposal will release sediments into the water column, which in turn have the potential to release some inorganic nutrients. However, the sediments in the lower Columbia River generally have very low organic levels (5 percent or less), which suggests that the release of inorganic nutrients will be small. In addition, any release of inorganic nutrients during dredging will be confined primarily to the bottom of the navigation channel. Given the nutrient input levels necessary to disrupt the nutrient balance within the Columbia River, the proposed activities are not likely to have a discernible effect on nutrients in the action area.

The accumulation of suspended materials in the turbidity maximum is an important sink for detritus and a source of entrained nutrients for food web consumers (Small, et al., 1990). The ETM also serves as a mechanism by which suspended materials and phytoplankton remain in the estuary longer in the face of the strong outward river flow (Sherwood, et al., 1990). In addition, actions of the ETM result in the lateral movement of suspended materials into peripheral areas, where they become available to suspension feeders and, as they settle, to deposit feeders in shallow water areas. The potential effect of the Project on the ETM is addressed in Section 6.1.5, Salinity. Changes that could occur to the ETM as a result of the Project are not expected to increase or decrease nutrients available to salmonids in the estuary.

River Mouth

See Estuary, above.

6.1.12.2 Conclusion

Any nutrient release that occurs as a result of sediment disturbance is expected to be small because of the low percentage of organic materials in the action area. In addition, effects of nutrient releases that occur are expected to be minimal overall because of rapid transport and dilution in the navigation channel. Although small amounts of nutrients will likely be released during dredging and flowlane disposal, because tidal hydrology and flow are dynamic in the system, the buildup of nutrients to levels that could result in algal blooms is not expected. In addition, changes to the ETM are not expected to cause any change in nutrient quantity or location as they relate to salmonids.

6.1.13 Imported Phytoplankton Production

During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease the production of imported phytoplankton.

6.1.13.1 Increase/Decrease in Imported Phytoplankton Production

Riverine Reach

See Estuary, below.

Estuary

Salmonids feeding in the water column eat prey that in turn, feed on plankton and microdetritus. It is believed that, since flow regulation, the food web has been fundamentally altered from one supported primarily by marsh macrodetritus to one supported mainly by imported microdetritus (Sherwood, et al., 1990; Weitkamp, 1994). This shift has resulted from the following:

- Loss of marsh areas as a result of diking
- Loss of marsh areas associated with other filling activities not related to channel deepening
- An increase in imported plankton as a result of increased production in Columbia River reservoirs

It is uncertain whether this shift has adversely affected juvenile salmonids.

A major zone for cycling of imported plankton is at the ETM. Because salinity may intrude farther into the estuary as a result of deeper channel depth, the point where imported phytoplankton contact dilute seawater and die will be farther upstream from present conditions. The location is coincident with that of the ETM. Because the slight shift in the ETM will often occur the natural variation of the ETM location, there is no expectation that the shift will have a discernible effect on imported phytoplankton.

River Mouth

See Estuary, above.

6.1.13.2 Conclusion

Modeling by OHSU/OGI and WES predicts a minor upstream shift in the ETM of up to 1 mile. This will affect the location where imported phytoplankton contacts dilute seawater and, therefore, the location where imported phytoplankton die and are broken up and processed. However, no change in type or quantity of imported phytoplankton within the system is anticipated. As noted in Section 6.1.5, Salinity, the shift in the ETM and salinity will affect the location of phytoplankton mortality. It is not anticipated that this will affect salmonids; however, this will be discussed further in an interagency workshop on the ETM.

6.1.14 Resident Phytoplankton Production

During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease the production of resident phytoplankton.

6.1.14.1 Increase/Decrease in Resident Phytoplankton Production

Riverine Reach

See Estuary, below.

Estuary

Salmonids feeding in the water column eat prey that feed on plankton and microdetritus. Because of loss of marsh areas and an increase in imported plankton, it is believed that the food web has been fundamentally altered from one supported primarily by marsh macrodetritus to one supported mainly by imported microdetritus (Sherwood, et al., 1990; Weitkamp, 1994).

Resident phytoplankton have always contributed to the food web in the estuary. Their contribution to total system phytoplankton may have been reduced since the increase in abundance of the upriver species. Upriver abundance and species have been changed by the increase in habitat provided by the reservoirs. It is uncertain whether this shift has resulted in a net negative effect on juvenile salmonids, but the Project will not affect this situation. An upstream relocation of the ETM could potentially result in enhanced resident phytoplankton production in this area. However, it is likely that the slight shift in the ETM will be well within the natural variation of the ETM location, resulting in no discernible effect on resident phytoplankton.

River Mouth

See Estuary, above.

6.1.14.2 Conclusion

Modeling by OHSU/OGI and WES predicts a minor salinity upstream shift of up to 1 mile. This shift may result in a slight shift in the ETM as well, which may enhance of resident euryhaline phytoplankton production. As noted in Section 6.1.5, Salinity, the shift in salinity, with its associated effects on phytoplankton production, is not anticipated to affect salmonids. However, this will be discussed further in an interagency workshop on the ETM.

6.1.15 Benthic Algae Production

During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease benthic algae production.

6.1.15.1 Increase/Decrease in Benthic Algae Production

Benthic algae consist primarily of benthic diatoms that occur on sediment grains and larger inorganic material and on macrophytes as epiphytes. Benthic macroalgae (e.g., green seaweeds such as *Ulva* spp. and *Enteromorpha* sp.) can also be abundant in some areas. There will be no dredging in the shallow flats and channels where benthic algae primarily occur. Flowlane disposal is not expected to affect benthic algae because it is done below the depth range where benthic algae occur, about 1 meter below MLLW.

Nutrients will likely be released during dredging and flowlane disposal. However, as discussed in Section 6.1.9, Nutrients, tidal hydrology and river flow should prevent the buildup of nutrients to levels that result in substantial algal blooms. Furthermore, benthic algal productivity is generally not nutrient limited, so increases in nutrients alone will not be sufficient to increase algae production.

Riverine Reach

No dredging or disposal activities are proposed for areas with significant benthic production. The closest potential effect would be from the shoreline disposal at Sand Island (O-86.2). However, the existing currents and erosion rates at the beach nourishment site create a coarse-grained and erosive environment that severely limits the potential for significant benthic production. Accordingly, no effects to benthic production are anticipated in the riverine reach.

Estuary

Because salinity will intrude farther into the estuary as a result of the deeper channel depth, the spatial distribution of benthic algae may change; any such change would occur primarily in the navigation channel, not in productive side channels or lateral habitats (see Section 6.1.5, Salinity). However, it is likely that the slight shift in the salinity will be undeterminable within the natural variation, resulting in no discernible effect on benthic production.

River Mouth

See Estuary, above.

6.1.15.2 Conclusion

Modeling by OHSU/OGI and WES predicts a minor upstream shift of salinity of less than a mile. Accordingly, there may be a small upstream shift in the location of benthic algae production, but this is very difficult to predict with any precision because many of the myriad diatom species consitituting the flora are euryhaline. As noted in Section 6.1.5, Salinity, the shift in salinity, with its associated effects on benthic algae production, is not anticipated to affect salmonids. However, this will be discussed further in an interagency workshop on the ETM.

6.1.16 Tidal Marsh and Swamp Production

Some individual juveniles of each of the 14 listed salmonids and coho may potentially use these habitats within the lower Columbia River. However, ocean-type chinook and chum salmon and young cutthroat trout are likely to commonly use the habitat.

Tidal marsh and swamps are an important habitat for juvenile salmonids that feed both epibenthically and in the water column. During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease tidal marsh and swamp production.

6.1.16.1 Increase/Decrease of Tidal Marsh and Swamp Production

The effects analysis for this indicator focused on the potential effect on tidal marsh and swamp production from changes in water surface elevation and salinity intrusion.

Riverine Reach

Marsh and swamp habitat occur sporadically along the riverine reach. Water surface elevation changes predicted in the FEIS (Corps, 1999a) range from zero to 0.18 foot. These slight changes are within the existing range of variability in the river system and are not anticipated to result in changes to habitat distribution or production because the changes are negligible compared to the natural variability of the system.

Estuary

As noted in Section 6.1.8, Tidal Marsh and Swamp Habitat, the structure, distribution, net production, and detritus production of marshes and swamps in the action area will not be significantly affected by the Project. Although OHSU/OGI and WES modeling results indicate slight changes to water surface elevation and salinity intrusion (see Sections 6.1.7, Bathymetry and 6.1.5, Salinity, respectively), these slight changes are not anticipated to result in changes to marsh distribution or production because the changes are negligible compared to the natural variability of the system.

In addition, even if slight changes in salinity intrusion occur, the salinity tolerances of plants within these habitats are much greater than the potential change. Accordingly, very minimal changes to tidal marsh and swamp production are anticipated.

River Mouth

See Riverine Reach, above.

6.1.16.2 Conclusion

While the Project is not anticipated to have a measurable effect on tidal marsh and swamp production, the Corps is proposing to conduct ecosystem monitoring that will assess changes to tidal marsh and swamp habitat. This monitoring will help validate the ultimate conclusions regarding tidal marsh and swamp productivity reached here. The proposed monitoring programs are discussed in Section 7.

6.1.17 Deposit Feeders

Ocean-type salmonids frequently feed on deposit feeders. During reconsultation, consideration was given to two potential ways in which the proposed Project could either increase or decrease the deposit feeders within the action area. First, whether dredging or disposal activities will have an effect on deposit feeder populations was considered. Second, whether changes in salinity within the estuary will affect deposit feeder populations was also considered. The second issue is assessed in Section 6.1.30, Habitat-Specific Food Availability.

6.1.17.1 Increase/Decrease of Deposit Feeders

Riverine Reach

See Estuary, below.

Estuary

Dredging will result in removal of some deposit feeders from the navigation channel. Flowlane disposal will bury some animals and, if deposition of sediments is heavy, will result in the loss of some communities. Removal and burial effects are expected to be relatively short-lived, with dredge and disposal areas being recolonized by deposit feeders. Deposit feeders occur in low densities in the navigation channel because the sand waves create constantly shifting habitat conditions. In these and other areas of the river, densities fluctuate as a result of constantly changing environmental conditions. No changes to deposit feeders are anticipated in shallow water areas, side channels, or embayments, which are the important locations for salmonid feeding opportunities.

River Mouth

See Estuary, above.

6.1.17.2 Conclusion

Limited removal and burying of deposit feeders will occur in portions of the navigation channel and deep water areas during the course of the Project. No significant change in deposit feeder populations is anticipated because the navigation channel does not provide suitable habitat. The Corps' proposed monitoring program, which will include a post-project survey of ecosystem conditions, will specifically address deposit feeders in shallow water areas.

6.1.18 Mobile Macroinvertebrates

During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease mobile macroinverebrate populations. Particular concern has been expressed concerning the impacts to Dungeness crab populations.

6.1.18.1 Increase/Decrease of Mobile Macroinvertebrates

Riverine Reach

Crayfish (*Pacifasticus trowbridgii*) occur primarily in the freshwater portions of the riverine reach near the shoreline, but are also found in the estuary. They are a food source for many fish species and may be eaten by adult or larger juvenile salmonids. However, they are not a significant aspect of salmonid diet, particularly for juvenile salmonids.

Estuary

Dredging will result in removal of mobile macroinvertebrates in the channel. Entrainment by dredges is generally lethal. In addition, flowlane disposal may temporarily bury some animals and, if deposition of sediments is heavy, will result in the loss of some members of the group. Removal and burial effects are expected to be relatively short-lived, with dredged areas being recolonized within 6 to 12 months (Flemmer, et al., 1997). Mobile macroinvertebrates located in shallow water, flats, and tidal marsh channels will not be affected.

Entrainment of Dungeness crab (*Cancer magister*), shrimp (*Crangon franciscorum*), and mysids (e.g., *Neomysis mercedis*) will occur in the project area; however, the entrainment is expected to be limited. Entrainment of Dungeness crab is likely to be limited because most Dungeness crabs occur in the lower part of the estuary outside of the project area or the main navigation channel. Large numbers of young of the year (YOY) Dungeness crab are carried into the lower portions of the estuary in the spring and early summer as they are carried inshore by ocean currents to rear. Adult crabs are abundant in the lower estuary in the shallow areas and Baker Bay where salinity levels are high enough to support them. An entrainment study done for the MCR Project (Larson, 1993) indicated that YOY crabs were entrained in larger number than juveniles and adults. Entrainment of *Crangon* and mysids is also likely to be small because they predominantly occur in the shallow areas over the tidal flats. They can also be found in the channel areas during low river flows. During this time, entrainment of these species may occur. During high flows the velocity is thought to be too great for them to be in the channel areas (CREDDP, 1984).

Indirect effects on macroinvertebrates from changes to temperature, salinity, and suspended sediments were also assessed, but were determined to be unlikely to cause lethal or sublethal effects on mobile macroinvertebrates. Because of the relatively wide salinity tolerances of most members of this group, slight shifts in salinity intrusion are not expected to change the abundance of mobile macroinvertebrates. Further, the proposed action is not expected to significantly affect temperature or suspended sediments (see Sections 6.1.35, Temperature and Salinity Extremes and 6.1.1, Suspended Sediments, respectively).

River Mouth

See Estuary, above.

6.1.18.2 Effects from Sediment Disposal on Dungeness Crab

Riverine Reach

Not applicable.

Estuary

See River Mouth, below.

River Mouth

Disposal of dredged material near the river mouth and offshore may bury crab and other members of this group. Studies have indicate that Dungeness crab are susceptible to burial and subsequent mortality. A laboratory study indicated that a portion of the soft-shelled crabs did not survive burial (Antrim and Gruendell, 1998).

Some mortality of Dungeness crabs from dredging and disposal operations will occur; however, this mortality is expected to have an insignificant effect on crab populations. In addition, although crab larvae are eaten by salmonids in other river estuaries, food studies in the lower Columbia River have indicated that these larvae are not a primary food source for salmonids in the lower Columbia River. In addition, crab are low in nutritional value because of the amount of chitin. See Table D4-2 in Appendix D-4 for additional information.

It is unlikely that the decrease in Dungeness crab will be significant enough to adversely affect salmonid populations.

6.1.18.3 Conclusion

Riverine Reach

See Estuary, below.

Estuary

Mobile macroinvertebrates in the estuary appear to be adapted to respond rapidly to disturbances and can recolonize areas following these disturbances. Changes to salinity intrusion, temperature, and suspended sediment are not expected to have an effect on the distribution of this group. It is predicted that there will be no effect on salmonids through loss or alteration of mobile macroinvertebrates in the navigation channel.

Some mortality of Dungeness crabs by dredging and disposal operations will occur; however, this mortality is expected to have an insignificant effect on crab populations in either the estuary or the river mouth.

As stated previously, although crab larvae are eaten by salmonids in other river estuaries, food studies in the lower Columbia River have indicated that these larvae are not a primary food source for salmonids in the lower Columbia River.

River Mouth

As stated previously, some mortality of Dungeness crabs by dredging and disposal operations will occur; however, this mortality is expected to have an insignificant effect on crab populations in either the estuary or the river mouth.

6.1.19 Insects

Insects include larval forms, as well as adults. These insects are associated with vegetated areas and also reside in the upper water column, often at the surface. They are most abundant in areas where current velocities are low and most feed directly on marsh vegetation. Insects are abundant and important to salmonids. Insect larvae and some adults are often found in the stomachs of salmonids that feed in shallow flats and marsh channels. All listed salmonids and coho could potentially feed on insects. The following analysis considers whether project activities will result in a potential increase or decrease of habitat for relevant insects within the food web.

6.1.19.1 Decrease of Insects

Riverine Reach

See Estuary, below.

Estuary

Insects are primarily freshwater organisms, but do occur in abundance in brackish water habitats. Increases or decreases in marsh habitat or production will have an equivalent effect on abundance and distribution of insects. However, as concluded in Section 6.1.8, Tidal Marsh and Swamp Habitat, the amount and characteristics of tidal marsh and swamp habitat along the shallow water margins of the lower Columbia River are not expected to be significantly affected by the proposed action.

Salinity intrusion, associated primarily with the main channel, is not expected to change the abundance of insects that are located primarily along the water margins in shallow wetlands and marsh channels. Since OHSU/OGI and WES modeling results suggest that anticipated changes to salinity in these areas are very small (see Section 6.1.5, Salinity), those changes should have an insignificant effect on relevant insect populations.

River Mouth

See Estuary, above.

6.1.19.2 Conclusion

Insects are abundant and important to salmonids. The proposed project is not anticipated to affect tidal marsh or swamp areas that support insect production. In addition, projected salinity increases are not expected to affect the distribution of this group. However, the Corps' proposed monitoring, which will include a post-project survey of ecosystem conditions, will include monitoring of habitat used by insects. (see Section 7).

6.1.20 Suspension/Deposit Feeders

Impacts to suspension/deposit feeders are the same as those to deposit feeders. (See Section 6.1.17, Deposit Feeders, for analysis). The Corps' proposed monitoring program, which will include a post-project survey of ecosystem conditions, will specifically address suspension/deposit feeders in shallow water areas (see Section 7).

6.1.21 Suspension Feeders

Impacts to suspension feeders are the same as those to deposit feeders. (See Section 6.1.17, Deposit Feeders, for analysis). The Corps' proposed monitoring program, which will include a post-project survey of ecosystem conditions, will specifically address suspension feeders in shallow water areas (see Section 7).

6.1.22 Tidal Marsh Macrodetritus

Tidal marsh and swamps are shown to be highly important habitat for juvenile salmonids that feed both epibenthically and in the water column. Small fish forage at edges of marsh channels for insects and benthic crustaceans. Production of prey resources is partially supported by marsh detritus.

6.1.22.1 Decrease in Tidal Marsh Macrodetritus

Riverine Reach

No changes are anticipated to occur within the riverine reach that would alter the amount or distribution of tidal marsh macrodetritus.

Estuary

Deepening the lower Columbia River channel is not likely to have a direct effect on the amount or productivity of tidal marsh macrodetrius. No dredging within the tidal marsh and swamp habitat is planned. Likewise, no filling of tidal marsh and swamp habitat is proposed as a part of the Project.

Tidal marsh and swamp habitat may increase slightly in area as a result of the channel deepening. The slight decrease in water surface elevation may provide more area that is at the appropriate depth for tidal marsh to develop (see Section 6.1.7, Bathymetry). This would allow marshes to expand and lead to an increase in tidal marsh and swamp macrodetritus.

River Mouth

See Estuary, above.

6.1.22.2 Conclusion

The amount and characteristics of tidal marsh and swamp habitat could potentially be slightly affected along the shallow water margins of the lower river and estuary through expansion. However, the potential changes are anticipated to be too small to be measurable. Nonetheless, the Corps' proposed monitoring, which will include a post-project survey of ecosystem conditions, will include estimates of tidal marsh macrodetritus (see Section 7).

6.1.23 Resident Microdetritus

Resident microdetritus, which is derived from benthic and planktonic algal production, is important to suspension feeders and suspension/deposit feeders. The primary potential for change to resident microdetritus would occur from changes caused by salinity intrusion.

6.1.23.1 Decrease of Resident Microdetritus

Riverine Reach

No changes are anticipated to occur within the riverine reach that would alter the amount or distribution of resident microdetritus.

Estuary

Because salinity may marginally intrude farther into the estuary as a result of the deeper channel,the spatial distribution of resident microdetritus may change slightly. However, as discussed in Section 6.1.5 Salinity, modeling results for potential changes in salinity associated with deepening the channel are anticipated to be minimal and are well within the natural variability of the system.

River Mouth

See Estuary, above.

6.1.23.2 Conclusion

There may be a small shift in the location of where resident microdetritus dies. This shift of the ETM is very difficult to predict because of the dynamic tidal and river hydraulics. It is not expected to affect salmonids.

6.1.24 Imported Microdetritus

Imported microdetritus is mostly derived from algal production upriver, including that produced above dams, and is important for suspension feeders and suspension/deposit feeders. Changes in the zone of contact between imported microdetritus and the salt wedge would occur in the estuary.

6.1.24.1 Reduction of Imported Microdetritus

Riverine Reach

No changes from current conditions are expected to occur to imported microdetritus upstream of the estuary.

Estuary

It is expected that no direct impacts will occur from the proposed Project to imported phytoplankton. Because salinity may intrude farther into the estuary as a result of the deeper channel depth, the point where imported phytoplankton contact dilute seawater will be farther upstream from current conditions. Specifics regarding changes in salinity are discussed in Section 6.1.5, Salinity.

River Mouth

See Estuary, above.

6.1.24.2 Conclusion

There may be a small shift in the location of where imported phytoplankton die. This shift is difficult to predict because of the dynamic tidal and river hydraulics. It is not expected to affect the overall amount of microdetritus.

6.1.25 Reduction or Increase of Habitat Complexity, Connectivity, and Conveyance

Tidal marsh and swamps and shallow water areas provide important habitats for juvenile salmonids. During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease the complexity, connectivity, or conveyance capability of these habitats.

Riverine Reach

See Estuary, below.

Estuary

No activities proposed for the Project would directly affect the complexity and connectivity of habitats within the estuary, riverine, or river mouth reaches. However, the primary concern for reconsultation is whether changes to habitat-forming processes will ultimately result in long-term changes to habitat complexity, connectivity, or conveyance. In particular, the potential effects from lowering the water surface elevation and changing salinity intrusion were considered.

As discussed in previous sections, OHSU/OGI and WES modeling results indicate slight changes to water surface elevation and salinity intrusion (see Sections 6.1.7, Bathymetry, and 6.1.5, Salinity, respectively). However, these slight changes are not anticipated to result in discernible changes to tidal marsh or shallows distribution or function because the changes are negligible compared to the natural variability of the system. In fact, OHSU/OGI modeling results indicate that channel deepening will result in almost no change in habitat opportunity hours, based on the depth criterion (see Section 6.1.7, Bathymetry).

River Mouth

See Estuary, above.

6.1.25.1 Conclusion

While the project is not anticipated to have a discernible effect on the location, function, or accessibility of tidal marsh or shallows habitat, the Corps is proposing to monitor any potential changes to the ecosystem from deepening of the navigation channel. The proposed monitoring programs are discussed in Section 7. Although the monitoring is not specifically targeted to habitat complexity, connectivity, and conveyance, it will provide information that will be useful for tracking these conditions in the future.

6.1.26 Velocity Field

Velocity field describes the speed and direction of fluid motion throughout the river system. As described in the conceptual model, the velocity field is an important indicator of salmonid growth because of its impact on refugia and feeding habitat opportunity. Changes in bathymetry from dredging and disposal that may change river velocity, and thereby affect habitat opportunity, were assessed as part of this analysis.

6.1.26.1 Effects on Habitat Opportunity Caused by Velocity Changes Resulting from Alteration of Bathymetry

Effects on habitat opportunity resulting from changes in water surface elevation are discussed generally in Section 6.1.7, Bathymetry. WES and OHSU/OGI both considered velocity specifically in their modeling analysis (see Appendices F and G).

Riverine Reach

Based on the predicted water surface changes (see Section 6.1.7, Bathymetry), velocity field changes are expected to be correspondingly small and have an insignificant effect on habitat opportunity.

Estuary

The WES model is three-dimensional, with model results for velocity averaged separately for the bottom and for the surface regions of the water column. Modeling results indicate that average velocity differences with the Project are small, ranging from approximately -0.2 foot per second to 0.2 foot per second. The largest differences are in the navigation channel. Differences in the shallow regions outside the navigation channel range from approximately -0.05 to 0.05 foot per second.

OHSU/OGI modeling supports the results of the WES model. The OHSU/OGI model presents velocity magnitude differences in terms of hours of habitat opportunity. Habitat opportunity, as defined by Bottom, et al. (2001), considers water depth and velocity conditions that provide favorable habitat for subyearling salmonids during their outmigration. In terms of velocity magnitude, habitat opportunity is defined as slow-moving environments with a velocity of less than 30 centimeters per second (approximately 1 foot per second). Using this definition of habitat opportunity, Table 6-1 shows the average number of hours in which the velocity criterion is met (over a 168-hour week) for the Cathlamet Bay region of the Columbia River estuary.

Modeling results were done for vertically averaged water column velocities and for minimum and maximum water column velocities. Both the spatial distributions and the area-weighted averages were similar for base and plan, indicating that channel deepening will have no effect on velocity magnitude. Maximum differences in average hours of approximately 10 to 15 percent (increase and decrease) between base and plan were predicted for model runs at both low and high flow. In these cases, the model runs for the Project scenario estimated higher habitat opportunity hours than the current situation.

Based on physical model results, the proposed Project will not cause significant changes to velocity in the shallow habitat areas of the lower Columbia River. WES modeling indicates base versus plan differences of less than 0.05 foot per second outside the navigation channel. The small computed differences in velocity for shallow areas between base and plan are much smaller than natural variations in velocity in these areas resulting from variations in freshwater flow and tidal dynamics. Furthermore, the computed differences in velocity between base and plan are smaller than the differences between computed velocity and observed velocity determined during model calibration.

River Mouth

Not applicable.

6.1.26.2 Conclusion

Based on modeling results, the proposed Project will not cause significant changes to velocity in the shallow habitat areas of the lower Columbia River. WES modeling indicates base versus plan differences of less than 0.05 foot per second outside the navigation channel. OHSU/OGI modeling actually indicates slight increases in habitat opportunity based on velocity. The small computed differences for both models are much smaller than natural ranges in velocity resulting from variations in freshwater flow and tidal dynamics. Furthermore, the computed differences in velocity between base and plan are smaller than the differences between computed velocity and observed velocity determined during model calibration. Velocity fields will be monitored as part of the Corps' monitoring plan (see Section 7).

6.1.27 Bathymetry and Turbidity (as Related to Salmonid Growth Opportunities)

The relevant aspects of bathymetry and turbidity in this section are the part they play in growth opportunities for salmonids. In the context of growth opportunity, this indicator refers to the ability of salmonids to see their prey. Because salmonids are visual predators, turbid waters may limit their ability to see prey, while uneven bathymetry may hide the prey from their sight.

6.1.27.1 Changes in Bathymetry

Riverine Reach

Changes to bathymetry could result to changes in the river level in this reach ranging from zero to 0.18 foot (approximately 2 inches) (see Section 6.1.7, Bathymetry). The analysis presented under Estuary, below, applies to this reach as well.

Estuary

As stated in Section 6.1.7, Bathymetry, the proposed Project could lead to changes in river bathymetry a number of ways, including:

- Dredging of material will directly increase water depth in dredged areas of the navigation channel by lowering the sediment bed elevation.
- Disposal of dredged material in-river will also affect water depth in some locations.
- The changes to channel geometry and river hydraulics can potentially alter the sediment dynamics in the system (see Section 6.1.2, Bedload, for discussion).

The primary changes to bathymetry will occur within the navigation channel. However, most salmonid feeding occurs in shallow water habitat areas. WES modeling indicates that areas outside of the navigation channel will undergo changes in water depth of less than 0.02 foot (approximately 1/4 inch). These small computed differences in water depth between base and plan are smaller than natural variations in water depth in the system that result from variations in freshwater flow and tidal dynamics. OHSU/OGI modeling supports the WES results and indicates that channel deepening will result in almost no change in habitat opportunity hours based on the depth criterion (number of hours that the water depth is between 4 inches and 6 feet for a given area). These changes are not anticipated to affect the ability of salmonids to find prey.

River Mouth

See Estuary, above.

6.1.27.2 Changes in Turbidity

As stated previously in Section 6.1.4, Turbidity, dredging and disposal operations are anticipated to increase turbidity in their immediate vicinity, at the time of their occurrence. These temporary increases could be several times background levels (for example, 25 NTU versus a background of 5 NTU). Dredging and disposal operations will occur at different times throughout the estuarine and riverine areas of the Project; disposal will also occur at the deep water site beyond the river mouth. Turbidity increases will be attenuated by turbulent mixing in riverine regions and by electrostatic effects caused by salinity in estuarine regions. In riverine and estuarine areas where neither dredging nor disposal is occurring, there will be no observable increase in turbidity.

Riverine Reach

See Estuary, below.

Estuary

Turbidity within the river will have short-term localized increases associated with dredging and disposal activities. As noted in Section 6.1.4, Turbidity, increases in turbidity levels from proposed activities are expected to be no more than 26 NTUs. Turbidity increases downstream of the activities will not exceed 1 NTU. As discussed in Section 4.1.1, these levels of turbidity are not sufficient to adversely affect salmonids.

River Mouth

See Estuary, above.

6.1.27.3 Conclusion

Riverine Reach

See Estuary, below.

Estuary

Changes to bathymetry and turbidity from proposed project activities will be minimal, localized around the actual navigation channel, and, in the case of turbidity, are anticipated to be only short-term changes. These changes are not anticipated to impair conditions that influence the ability of fish to locate their prey.

River Mouth

See Estuary, above.

6.1.28 Feeding Habitat Opportunity

The natural variability in the physical characteristics of lower Columbia River habitats affects the amount of total habitat available for use by young salmonids. The species/life stage most sensitive to changes in feeding habitat opportunity is ocean-type salmonids, which tend to feed near the shoreline and within zero to 2 meters of the surface. Generally the smaller ocean-type juveniles have the capacity to maintain sustained swimming speeds of 0.4 meter per second or greater over periods of hours (Davis, et al., 1963). For this reason, they can resist only relatively weak currents.

Yearling and older salmonids have less restrictive habitat requirements than juveniles and are consequently less susceptible to changes in feeding habitat opportunity. Generally, yearlings are not strongly shoreline-oriented, although some are found in shoreline areas. Yearlings tend to be surface-oriented, but feed over a relatively wide range of depths, from the surface up to 5 to 10 meters deep. Yearlings are commonly found in areas of both low and relatively high current speeds as they rapidly migrate downstream.

The only proposed action with the potential to affect feeding habitat opportunity is the dredging of the navigation channel. To have an effect, the dredging would need to cause substantial changes in water surface elevation, velocity (current speeds), salinity, or temperature. As discussed above and further below, the project is not expected to cause such changes.

6.1.28.1 Change in Water Surface Elevation, Velocity, or Salinity

Changes in water surface elevation, current speeds, or salinity resulting from the Project should not alter the location or amount of feeding habitat available to ocean-type juvenile salmonids. As discussed in Section 6.1.26 (Velocity Field), the anticipated change in velocity from the proposed action is expected to be minimal. In addition, the change in surface water elevation is expected to range from zero to 0.18 foot. and should not affect access to shallow water habitats (see Sections 6.1.5, Salinity, and 6.1.7, Bathymetry). Changes in salinity intrusion are also expected to be miniscule and are not expected to affect habitat opportunity (see Section 6.1.5, Salinity).

6.1.28.2 Change in Temperature

Temperature changes could occur within the estuary for a number of reasons, including salinity changes, depth changes, and velocity changes. Modeling results indicate that these potential factors for changing temperature conditions are not significantly altered by the proposed project activities. Model results indicate a negligible change in salinity for base versus plan conditions in all areas (see Section 6.1.5, Salinity). Model results also indicate negligible or no changes in depth and velocity for base versus plan conditions in all areas outside of the navigation channel (see Sections 6.1.7, Bathymetry, and 6.1.26, Velocity Field). Accordingly, changes in feeding habitat opportunity that result from temperature changes are not expected to occur.

6.1.28.3 Conclusion

Based on modeling results, the predicted changes in water surface elevations, velocities, salinity, and temperature are not enough to measurably change feeding habitat opportunity for young salmonids. However, as noted previously, the Project is expected to have no discernible effect on salmonid feeding habitat opportunity, but the Corps is proposing to monitor the variables that affect habitat opportunity to verify this conclusion (see Section 7).

6.1.29 Refugia

Refugia is a habitat function important to young salmonids because of their vulnerability to predators and need to escape currents in the river that exceed their swimming capacity (see Section 6.1.26, Velocity Field). Changes in refuge functions could occur through alteration of water surface elevation or flow velocity along shoreline habitats used by young salmonids during their rearing in the riverine and estuarine portions of the action area.

6.1.29.1 Changes in Water Surface Elevation

Riverine Reach

Shallow water and gently sloping shorelines are considered to provide refuge from fish predators; however, these same conditions increase exposure to some bird predators. This function is closely related to feeding habitat opportunity (see Section 6.1.28, Feeding Habitat Opportunity). Substantial changes in water depths in the range of several tenths of a meter or more might alter the amount or quality of shallow-water refugia available to juvenile salmonids. Within the estuarine and riverine reaches of the action area, water depths vary in the range of 2 to 9 feet within hours as a result of tidal forces. Seasonal changes in river discharge produce effects that increase this range by several meters. However, the modeling results indicate that changes in the surface water elevation caused by the Project are anticipated to be zero to 0.18 foot (approximately 2 inches).

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

6.1.29.2 Changes in Velocity

Refugia functions as an escape from environmental conditions that exceed the normal physical capacities of young salmonids, including ability to swim against currents.

Riverine Reach

Currents (Section 6.1.26, Velocity Field) are the environmental condition most commonly exceeding the swimming capacity of young salmonids in the lower Columbia River riverine and estuarine habitats. Side channels, bays, islands, and fixed structures such as piers and piles provide refuge from strong riverine and tidal currents that could potentially displace young salmonids. Generally the smaller ocean-type juveniles have the capacity to maintain sustained swimming speeds of 1.5 feet per second or greater over periods of hours (Davis, et al., 1963). These ocean-type juveniles have the capacity to resist only relatively weak currents. Substantial increases in riverine or tidal currents (more than 10 decimeters per second) within the shoreline habitat juveniles commonly occupy would alter the amount or location of the refuge available to them. However, the modeling results from WES and OHSU/OGI show that changes in velocity caused by the Project are anticipated to be no more than 0.05 foot per second in shallow areas.

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

6.1.29.3 Conclusion

The changes in water surface elevations projected within the estuarine and riverine reaches are not likely to alter the amount or location of refugia. In addition, changes to river current velocity from the proposed dredging are anticipated to be negligible (particularly in the side channels and shallow water areas that provide the refugia) and will not affect the function of the available refugia. The proposed monitoring program, which will include a post-project survey of habitat conditions, will specifically address refugia (see Section 7).

6.1.30 Habitat-Specific Food Availability

Young salmonids migrating through the lower Columbia River and estuary are rearing as they move. Ocean-type juveniles, in particular, spend prolonged periods rearing in shallow water areas within the estuary. Prey available to young salmonids rearing in the action area varies between freshwater and saltwater influenced areas, as well as between open water and shallow benthic areas. Prey also varies with seasons.

Prey availability is potentially influenced by changes in the physical habitat that alter the amount or distribution of shallow water habitats used by young salmonids. Three potential sources of effect have been assessed to determine whether changes to habitat-specific food availability will occur:

- Loss of shallow water area from side-slope adjustment
- Loss of shallow water and flats area from lowering of surface water elevations
- Changes in habitat-specific food availability as a result of changes in salinity

The first two sources of effect have already been dealt with in Sections 6.1.2, Bedload and 6.1.7 Bathymetry, respectively. Accordingly, the analysis in this section focuses on potential changes in food sources that may result from anticipated changes in salinity.

6.1.30.1 Changes in Habitat-Specific Food Availability as a Result of Changes in Salinity

Minor changes in salinity are not likely to produce changes in the shallow water and flats habitat that affect salmonids, including habitat-specific food availability. Existing salinity conditions within the estuary vary daily with tide condition and seasonally with changes in river discharge. Daily changes at specific locations can vary from low salinities of less than1 ppt to as high as 15 to 20 ppt. Modeling (see Section 6.1.5, Salinity) indicates an increase in salinity of from 0.1 to 0.15 ppt in shallow areas of the estuary, such as Cathlamet and Grays Bays.

Riverine Reach

The riverine reach is freshwater and is not affected by salinity.

Estuary

A review of salinity tolerances of *Corophium salmonis*, a major benthic invertebrate prey item for juvenile salmonids (Weitkamp, 1994), indicated a tolerance to salinity variations and the ability to recover following major perturbations in salinity conditions. However, changes in the range of 1 ppt may influence the distribution of *Corophium* at the extremes of its range at the downstream and upstream edges of its distribution (Holton, 1984). *Corophium* may not occur as far downstream as they currently do in the deeper portions of the river channel. However, most *Corophium* consumed by young salmonids are likely produced in the shallow habitats where the young salmonids feed. Salinity changes of 0.1 to

0.15 ppt in the surface water within these habitats are unlikely to affect the distribution of *Corophium* in areas where salmonids feed.

The change in shallow water salinity, in view of the much greater natural variation caused by tides and river flow, is unlikely to result in a measurable change in the species distribution of various shallow water and flats species within the estuary. Also, the extent of salinity distribution within the action area is unlikely to change within the shallow water and flats habitat areas.

River Mouth

See Estuary, above.

6.1.30.2 Conclusion

Prey resources for larger juvenile salmonids occupying the water column are not likely to be altered by the slight physical changes resulting from the Project. Physical changes within the shallow water areas where juvenile salmonids feed are not measurable and are not expected to affect juvenile food availability. However, the Corps' proposed monitoring program, which will include a post-project survey of ecosystem conditions, will address food availability (see Section 7).

6.1.31 Contaminants

This section examines whether the proposed Project adds to existing risks posed by bioaccumulative contaminants to juvenile salmonids that feed on epibenthic invertebrates when they are present in the action area. The contaminants examined focused on compounds that are environmentally persistent and bioaccumulate in fish and invertebrates, namely total polychlorinated biphenyls (ΣPCBs), total DDT and metabolites (ΣDDT), and total polyaromatic hydrocarbons (ΣPAHs). Because of the contaminants' physical properties, juvenile salmonids bioaccumulate them principally from food rather than from water. For hatchery fish, a key contaminant source is the hatchery food. For both hatchery and naturally produced stocks, key sources are areas where the sediments are highly contaminated by point sources of pollution.

6.1.31.1 Increase in Availability of Contaminants

In sediments, contaminants are absorbed to the organic carbon in silt, which is part of the fine particulate fraction (less than 0.064 micron in size). The microbial biofilm that accumulates on the surface of organic particles constitutes the food of certain types of epibenthic invertebrates; together, they make up the pathway by which these contaminants enter food chains involving juvenile salmonids. Preliminary evidence obtained by NMFS suggests that some salmonids may be at risk of being stressed by contaminants contained in the tissues of their epibenthic prey (L. Johnson, 2000). Dredging and disposal suspends fine particulates, and it has been hypothesized that these particulates may be deposited in an area where epibenthic prey of juvenile salmonids thrive. Within this zone, the contaminants may be more accessible to juvenile salmonid prey. Therefore, there is some potential for risk, and the purpose of this assessment was to examine risks from dredging sediments within the channel. Risks from sediments outside of the channel were examined in comparison to those associated with channel sediments.

A risk-based approach was used to address this question. The entire analysis is described in Appendix B. Figures B-1 through B-3 of that appendix summarize the results of the risk analyses for the lower estuary (RM zero to 40) for all three contaminant classes. These risk estimates are presumed to apply to all salmonids, including hatchery fish and nonendangered species. As can be seen from all three graphs, only negligible risks were predicted for the channel sediments that are proposed for dredging.

ΣPCB risks in the channel are negligible. Likewise, all ΣDDT exposures via channel sediments were below both the regional screening guideline and a lowest observed effect threshold developed from testing of cutthroat trout (Figure B-2). Cutthroat trout appear to be the salmonid most sensitive to DDT, so these results should apply to other juvenile salmonids. Finally, all ΣPAH exposures associated with channel sediments were lower than four effects criteria. For example, channel sediment ΣPAH concentrations were 41 parts per billion (ppb) dry weight or lower, whereas the most conservative effect criterion, proposed by Johnson (2000), was 54 ppb dry weight. Other ΣPAH effect criteria were much higher: 1,000 to 15,100 ppb dry weight (Figure B-3). For all contaminants, risks from shoreline sediments were higher than for channel sediments, and they were higher upstream than in the lower Columbia River.

Risks to the sediment-dwelling invertebrate prey of salmonids in channel sediments also were negligible, and the findings were very similar to those for juvenile salmonids, even though different methods were used to define what contaminant concentrations they might be exposed to and the toxicity of these contaminants.

The potential for cumulative risks appears negligible because all contaminants posed negligible risks. Because their specific modes of action are different and exposures were below effects thresholds, risks from PAHs, PCBs, and the DDT family are not additive. This result supports the overall conclusion concerning negligible risk potential to juvenile salmonids in the lower Columbia River as a result of the proposed Project.

Riverine Reach

Risks associated with Project sediments were negligible. Risks to salmonid juveniles were highest in the shoreline, non-project sediments of the riverine reach because there is a greater concentration of urban and industrial point sources in the Portland-Vancouver-Longview region; however, these levels should not exceed EPA/DMEF screening levels. Project actions will only occur in those areas when berths are being deepened. Sediment samples have shown that the materials to be dredged in these berths are suitable for in-water, unconfined disposal (see Section 3.2.4, Berth Deepening at Lower Columbia River Ports).

Estuary

Navigation channel sediments posed negligible risks. Risks were lower in the estuarine reach as compared with upstream reaches because there are fewer urban and industrial sources and greater, tidally driven dilution of contamination by ocean water.

River Mouth

Contaminant risks appear lowest in the river mouth reach because it is distant from most urban and industrial contaminant sources and its sediments and waters are most diluted tidally by oceanic water.

6.1.31.2 Conclusion

The potential for cumulative risks appears negligible because all contaminant levels posed negligible risks. Because their specific modes of action are different and exposures were below effects thresholds, risks are not additive. This result supports the overall conclusion concerning negligible risk potential to juvenile salmonids in the lower Columbia River as a result of the proposed Project. Monitoring actions for this indicator are addressed in Section 7.

6.1.32 Disease

Disease agents in salmonids of the Columbia River system include parasites, bacteria, and viruses. Many of the parasites and some of the bacteria co-exist with healthy fish, causing no observable decrease in fitness. However, it is possible that stress may induce such symbiotic relationships to become pathogenic by decreasing the immune capacity of the host fish (National Oceanic and Atmospheric Administration [NOAA], 2001) . Stress may be induced by environmental changes that are outside the variations normally experienced by salmonids. Crowding in fish hatcheries, fish ladders, or other areas of restricted habitat causes stress and also increases the chance of transmitting disease agents from sick fish to healthy fish. Increased water temperature, decreased flows, or reduced food availability are other possible stress factors. The preceding analysis of these parameters does not identify changes that are likely to cause immuno- suppression. Likewise, increases in levels of contaminants that may adversely affect the immune system (e.g., dioxins) as a result of this action are not predicted to occur (see Section 6.1.30, Habitat-Specific Food Availability, and Appendix B).

Riverine Reach

See above.

Estuary

See above.

River Mouth

See above.

6.1.32.1 Conclusion

No changes that are likely to substantially increase stressors for salmonids are anticipated. Accordingly, no increases in disease are expected as a result of proposed project activities.

6.1.33 Suspended Solids

Suspended solids are a factor in salmonids survival for a variety of reasons, including:

- The organic matter is a potential source of biological oxygen demand in the water column (addressed in Section 6.1.33, Suspended Solids).
- The organic material may be a pathway of transfer of contaminants to fish (addressed in Section 6.1.31, Contaminants).
- The material may have a detrimental effect on fish through clogging of gills (addressed in Section 6.1.33, Suspended Solids).
- The associated turbidity may impair feeding by reducing the ability of fish to see prey (addressed in Section 6.1.27, Bathymetry and Turbidity).

- Turbidity can also benefit juvenile salmonids by making them less susceptible to predation (addressed in Section 6.1.36, Turbidity).

As discussed in Section 6.1.1, Suspended Sediment, some changes to the sediment portion of suspended solids are expected to occur during construction and maintenance dredging activities at both dredging and disposal locations. Both dredging and disposal will occur in the estuarine and riverine environments, and disposal will also occur in the open ocean beyond the river mouth. The potential effects on salmonid prey and predation from changes in suspended solids are covered in Sections 6.1.27, Bathymetry and 6.1.36, Turbidity respectively. Consideration of changes in levels of the organic component of suspended solids is provided below. In addition, the potential for suspended solids to reach levels necessary to cause gill clogging is also discussed below.

6.1.33.1 Changes to Suspended Solids

Riverine Reach

See Estuary, below.

Estuary

The proposed dredging associated with the Project will occur within the navigation channel and will primarily entail removal of sand and sediments. Disposal activities will involve only those materials removed during dredging. The material at the bottom of the navigation channel is composed of over 99 percent sand and is low in organic content. The organic input to the system comes from both upriver sources and from tidal marsh and swamp areas. The proposed project activities are not anticipated to affect either of these sources (see Section 6.1.8, Tidal Marsh and Swamp Habitat). Accordingly, the proposed activities are not anticipated to alter the concentration or distribution of organic material within the river or estuary.

The likelihood of increased suspended solids causing gill clogging in migrating salmonids depends on a number of factors, including:

- Duration of exposure to suspended solids
- Concentration of suspended solids
- Particle size of suspended solids
- Angularity of suspended solids

The highest increases in suspended solids concentrations are anticipated to be localized and short term, occurring near the dredging and disposal operation (see Section 6.1.1, Suspended Sediments). The likely exposure for salmonids will be to the low concentrations (zero to 2 mg/L increases) that will occur downstream from dredging and disposal operations. In addition, less than 1 percent of dredged material will consist of the fines that are the cause of gill clogging (Sigler, et al., 1984). Accordingly, the anticipated slight increases in suspended solids will not be of a sufficient intensity or nature to cause gill clogging in salmonids.

River Mouth

See Estuary, above.

6.1.33.2 Conclusion

The organic component of suspended solids, which can cause the problems identified above for salmonids, is not expected to increase as a result of the proposed Project. Notable increases in sediments will occur only in localized areas and for short periods. To the extent that there are increases in the sediment portion of suspended solids, the effects are discussed in Section 6.1.1, Suspended Sediment.

6.1.34 Stranding

Subyearling salmonids rearing in water less than 3 feet deep can potentially be stranded by water level fluctuations. The following discussion focuses on whether changes in ship wakes will occur that will change the potential for stranding of salmonids.

6.1.34.1 Stranding Related to Ship Wakes

Fish encounter continuous water fluctuations, with tidally produced declines occurring twice each day. Thus, they appear to be adapted to surviving water level declines of several to many inches per hour. Likewise they commonly encounter storm-induced waves during their estuarine residence period. These waves range in height from 4 inches to several feet, depending on speed, fetch, and duration of the prevailing wind. These storm waves generally build up over short periods of time, likely giving the fish adequate opportunity to detect the worsening condition and move away from shallow areas where they might be stranded.

Unlike storm waves, ship generated waves will reach shoreline rearing areas with little warning. With beach slopes of 0.02to 0.1 foot per feet, these waves hypothetically could deposit fish from very shallow water to the dewatered portion of the beach.

Riverine Reach

The stranding of fish from ship wash is directly related to the size of the waves generated. Wave size is primarily a function of ship speed and is secondarily influenced by channel depth, distance from shore, and vessel draft. This suggests that regulating speeds of commercial marine traffic is one effective way to reduce potential stranding by large draft vessels. However, similar but more recent studies conducted in 1992 and 1993 showed little stranding as a result of wave action generated by large draft vessels. Just five juvenile salmonids were found to have been stranded on shore as a result of wave action (Hinton and Emmett, 1994). A 2001 analysis of whether the deeper draft ships will produce larger waves in a deeper channel indicates that little if any change is expected (Hermans, SEI Presentation, 2001) (see Section 6.1.1.3, Suspended Sediment Caused by Ship Wakes).

In addition to the deeper channel not causing increased wave sizes, it is also not expected to cause more frequent waves. The FEIS found that “channel deepening in itself will not induce additional ship traffic” or “contribute to development of additional ports or port facilities” (Corps, 1999a). This is consistent with historical vessel traffic trends on the Columbia River, as well as the market forces that drive port facility development.

Historical data for the existing 40-foot channel shows that the total tonnage carried by ocean-going vessels calling at the lower Columbia River ports has more than tripled since Congress authorized the deepening from 35 to 40 feet in 1962, while the number of vessel transits has actually decreased slightly. The same trend is expected if the channel is deepened to 43 feet. Regional and national commodity forecasts project cargo volumes transiting the lower Columbia River will double or triple over the next 20 years, but a deeper channel will likely reduce or moderate the volume of vessel traffic relative to a "no channel deepening" scenario.

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

6.1.34.2 Conclusion

The Project is not expected to produce either a direct or an indirect effect on stranding of young salmonids. The Project is designed to provide greater navigation reliability and efficiency with existing vessels – not to increase the number of ships using the channel. In addition, vessel speeds and wakes are not expected to measurably change with the deeper channel. Thus, the stranding conditions are not likely to change with the proposed Project. However, the Corps proposes to conduct field surveys during juvenile outmigration to verify this conclusion (see Section 7).

6.1.35 Temperature and Salinity Extremes (as Related to Salmonid Survival)

Temperature and salinity extremes are important factors affecting juvenile salmonid survival, migration, and ocean entry. Because the Columbia River is water quality limited for temperature, it is particularly important to determine the extent to which the Project might change the temperature profile in the lower Columbia River and estuary system.

The primary project activities that have the potential to change salinity and temperature are dredging and in-water disposal. Although dredging will occur sporadically throughout the navigation channel from RM 3 to RM 106.5, most of the in-water disposal will occur downstream from RM 36.

6.1.35.1 Changes to Salinity

As discussed in Section 6.1.5, Salinity, alteration of the channel bathymetry, resulting from dredging and flowlane disposal, has the potential to change the relative balance between upstream freshwater velocities and ocean tidal forces.

Riverine Reach

Not applicable.

Estuary

Because longitudinal salinity gradients occur in the estuary portion of the system (RM 3 to 40), this is the area of concern with regard to impacts on salinity gradients. However, while salinity changes greater than 1 ppt are predicted to occur at the bottom of the navigation channel, changes at a given location in the shallow embayments of the estuary (especially in Cathlamet Bay) are predicted to be less than 0.1 to 0.15 ppt.

It should also be mentioned that the very small computed differences between base and plan for salinity in shallow areas are much smaller than natural temporal variations in these areas as a result of variations in freshwater flow and tidal dynamics. In other words, while the model predicts that some change is likely, that change will not be discernible given the large daily, monthly, and seasonal variations in the conditions affecting salinity in the estuary (see Section 6.1.5, Salinity).

River Mouth

See Estuary, above.

6.1.35.2 Changes to Temperature

The proposed Project's potential for affecting temperature in the action area is through alteration of tidal intrusion in the estuary. Other possible effects to temperature from the Project are from changes to velocity or depth.

Riverine Reach

Changes in water depth and velocity in this area are two other factors affected by the Project that could potentially affect temperatures. However, model results indicate negligible or no changes in depth and velocity for base versus plan conditions in all areas outside of the navigation channel (see Sections 6.1.7, Bathymetry, and 6.1.26, Velocity Field).

Estuary

Altering bathymetry has the potential to change the relative mix of upstream freshwater and ocean water. This ocean/freshwater mix occurs in the estuary portion of the system (RM 3 to 40); therefore, this is the primary area of concern for affecting temperature gradients.

The primary factor potentially affecting temperatures would be an increased penetration of cooler ocean water under plan conditions. This would reduce rather than increase the temperature of estuarine waters during summer months. However, model results indicate a negligible change in salinity for base versus plan conditions in all areas (See Section 6.1.5, Salinity). Therefore, a change in temperature as a result of increased intrusion is not anticipated.

River Mouth

See Estuary, above.

6.1.35.3 Conclusion

The modeling performed by WES and OHSU/OGI indicate that the physical factors most likely to result in changes in temperature and salinity will not be significantly affected by the proposed Project. Accordingly, no significant change to temperature or salinity is anticipated. However, the Corps proposes to conduct monitoring of temperature and salinity before, during, and after construction to verify this conclusion.

6.1.36 Turbidity

Increases in turbidity can reduce the ability of predators to see salmonids. This could increase survival of salmonids. A complete discussion of increases in turbidity levels is provided in Section 6.1.4, Turbidity. Turbidity aspects related to growth are discussed in Section 6.1.27, Bathymetry and Turbidity.

6.1.36.1 Decreased Predation and Ability to Feed Caused by Turbidity

There is the potential for short-term and localized elevation of turbidity levels during deepening and maintenance dredging activities at both dredging and disposal locations. These activities will occur in both estuarine and riverine environments; disposal will also occur in the open ocean, beyond the river mouth.

Riverine Reach

See Estuary, below.

Estuary

Increases in localized turbidity levels of 5 to 26 NTUs are possible as a result of proposed project activities. These increases will be short term (less than an hour) and confined to areas where dredging and disposal will occur. In riverine and estuarine areas where neither dredging nor disposal is occurring, there could be a zero to 1 NTU increase in turbidity levels.

River Mouth

See Estuary, above.

6.1.36.2 Conclusion

Temporary increases in turbidity are anticipated to occur in localized areas where dredging and disposal will occur. Changes to turbidity levels in shallow water areas outside of the active disposal areas are unlikely to exceed 1 NTU. Therefore, it is not expected that survival of salmonids will change from turbidity caused by the Project.

6.1.37 Predation

Predation is a major cause of the loss of young salmonids during their migration to the ocean. Because historical dredge material disposal practices led to the creation of additional predator habitat within the estuary, the analysis for the currently proposed project activities addresses steps taken to prevent a similar situation. Predation rates on young salmonids are potentially affected by factors that either influence the abundance of predators or the exposure of the young salmonids to predators. Substantial changes in habitat characteristics, not anticipated as a result of this Project, are the most likely cause for these effects.

For a detailed discussion of potential changes to habitats within the action area, see Sections 6.1.8 (Tidal Marsh and Swamp Habitat), 6.1.9 (Shallow Water and Flats Habitat), and 6.1.10 (Water Column Habitat).

Riverine Reach

See Estuary, below.

Estuary

Predation of juvenile salmonids is primarily by avian predators such as Caspian terns and cormorants. Past enhancement of avian predator habitat occurred as a result of creating upland habitat through dredge disposal. To ensure that the proposed Project does not repeat this, no disposal is planned for areas that would create or expand upland habitat areas that could be colonized by these predators. Adult salmonids are preyed on primarily by marine mammals and man during their return migration through the action area. No changes have been identified that are likely to alter the predation rates on adult salmonids.

River Mouth

See Estuary, above.

6.1.37.1 Conclusion

No changes to habitat areas are anticipated that would change the abundance of predators or salmonid exposure to those predators. Accordingly, no effects to predation on salmonids are expected as a result of the proposed Project.

6.1.38 Entrainment

Two potential effects from entrainment have been considered during the reconsultation process. First, the potential for salmonids to be directly entrained during dredge operations has been assessed. Second, the effects of entrainment of salmonid prey species during dredging operations have been considered.

6.1.38.1 Entrainment of Salmonids

The only documented entrainment of salmonids occurred during a study in which the dredge draghead was operated while elevated in the water column instead of on the channel bottom and while pumping (R2 Resource Consultants, 1999). No juvenile salmonids have been entrained during normal dredging operations (Larson and Moehl, 1990).

Dredging procedures call for the draghead to be buried in the sediment of the riverbed during dredging operations or raised no more than 3 feet off the river bottom when the pumps are idling to further reduce the potential for fish entrainment. Adult salmonids have sufficient swimming capacity to avoid entrainment by dredging if they are present in the vicinity of dredges and if the draghead is above the riverbed when operating. As noted in the discussion of pipeline and hopper dredging in Section 3, BMPs for dredging operations require that the dredge pump not be operated when the draghead is raised more than 3 feet above the river bottom.

Riverine Reach

It is not anticipated that any fish will be entrained during dredging operations in this reach.

Estuary

See Riverine Reach, above.

River Mouth

No dredging activities for the Project will occur within this reach.

6.1.38.2 Entrainment of Salmonid Prey

Entrainment of salmonid prey has been assessed to determine the potential to produce indirect impacts to young salmonids through loss of prey resources.

Riverine Reach

It is likely that benthic invertebrate prey such as *Corophium* will be entrained in active dredge areas within the navigation channel. However, the benthic prey consumed by young salmonids come primarily from the large areas of shallow water in the lower Columbia River, where channel dredging will not occur.

Entrainment of planktonic prey also potentially occurs during dredging. Prey resources such as *Daphnia* and similar organisms will be entrained. However, these planktonic invertebrates are numerous throughout the water mass of the lower Columbia River. The portion of the population lost through the small portion of the water mass entrained will be small compared with the amount lost continuously from the lower river in the river's discharge to the Pacific Ocean.

Estuary

See Riverine Reach, above.

River Mouth

No dredging activities for the project will occur within this reach. Also, for a discussion on the potential for entrainment of Dungeness crab, see Section 6.1.18, Mobile Macroinvertebrates.

6.1.38.3 Conclusion

Entrainment is not anticipated to have an effect on salmonids because BMPs will be followed that reduce entrainment of salmonids. In addition, salmonid prey that are entrained in the estuary will be limited to the navigation channel, where benthic productivity is low.

6.2 Effects on Pathways

This section addresses the specific effects of the project on the respective indicators at a broader ecological level of analysis. The effects discussed in Section 6.1 for individual ecosystem indicators are linked to a larger ecosystem scale by addressing how these effects might change pathways. This integrated approach considers the links inherent within the system, analyzing each of the ecosystem pathways identified in the conceptual model (habitat-forming processes, habitat types, habitat primary productivity, food web, growth, and survival).

6.2.1 Habitat-Forming Processes Pathway

Sections 6.1.1 through 6.1.7 discussed potential changes to the seven physical processes that are important to forming the habitats relied on by salmonids. The following potential changes to those processes were identified:

- There will be short-term, localized increases in suspended sediment concentrations in the immediate vicinity of dredging and disposal operations (see Section 6.1.1, Suspended Sediment).

- The Project may temporarily shift the direction of bedload movement along the sides of the navigation channel as a result of side-slope adjustments, which may cause erosion at some previous beach nourishment sites (see Section 6.1.2, Bedload).

- There will be short-term, localized increases in turbidity levels in the immediate vicinity of dredging and disposal operations (see Section 6.1.4, Turbidity).

- Salinity increases of less than 0.5 ppt in the shallow embayments of the estuary (e.g., Cathlamet Bay, Grays Bay) will occur. Salinity increases up to 5 ppt would occur in the bottom of the navigation channel (see Section 6.1.5, Salinity).

- The salinity wedge could potentially be shifted upstream up to a mile (see Section 6.1.5, Salinity), resulting in a possible shift in the ETM location.

- Bathymetric changes will include up to 3 feet of deepening in areas of the navigation channel that are currently shallower than -48 ft CRD and some rise in the riverbed at shoreline and flowlane disposal sites. In addition, there is a potential for zero to 3 feet of deepening along the side slopes adjacent to the dredge cuts (see Section 6.1.2.1, Potential Reduction in Volume of Bedload Caused by Removal of Channel Materials). Water surface elevation could be affected between RM 80 and 146. The decrease could be as much as 0.18 foot at the upstream end of the Project (see Section 6.1.7, Bathymetry).

Individual indicators and their potential effect on habitat-forming processes are discussed in the following paragraphs.

6.2.1.1 Increased Suspended Sediment

Suspended sediments are an important component of the habitat-forming process. There may be as much as a 4.5 percent increase in the total suspended sediment load in the lower Columbia River as a result of the Project. Increased suspended sediment levels would tend to improve habitat-forming processes in the estuary by providing additional materials to form tidal marsh and swamp habitat. However, the increased suspended sediment load is likely too small to have a measurable effect on habitat-forming processes.

6.2.1.2 Side-Slope Adjustment

The proposed Project will result in some side-slope adjustment as a result of altered bedload transport direction within the action area. This process will not affect water column or tidal marsh and swamp habitats. The side-slope adjustment process will take 5 to 10 years. Over that time, shallow water and flats habitat at six historical shoreline disposal sites will tend to move shorewards into former areas of artificial beach that have slowly eroded. All of these shoreline sites have been used in the past for dredge disposal. Two of the six historical shoreline disposal sites (Sand Island, RM 86.2, and Miller Sands, RM 22.5) will be used throughout the life of the Project. Because the bedload transport rate during maintenance sideslope adjustment is the same rate at which normal bedload transport would occur without the Project (just in a different direction), the quantity and quality of shallow water and flats habitat is expected to remain constant in the river and estuary reaches.

6.2.1.3 Increased Turbidity

Short-term localized turbidity levels of 5 to 26 NTUs that might be caused by the proposed action are not likely to produce detectable effects on plant growth in the lower river.

Not only is the amount of increase too low, but it will be localized to areas where dredging and disposal will occur. The highest levels of turbidity will occur in deep water and sandy beach areas that are not salmonid habitat.

6.2.1.4 Salinity Increases

The computed differences in modeling between base and plan for salinity in shallow areas are much smaller than natural temporal variations due to normal variations in freshwater flow and tidal dynamics. Differences computed for the channel bottom are increases up to 5 ppt. This will not affect habitat-forming processes in any of the three habitat types.

6.2.1.5 ETM Shift

The potential shift of the ETM would occur in a relatively small part of the south channel (see Section 6.1.5, Salinity). It would generally remain within the current range or path of the ETM, with up to a 1-mile shift in the upstream boundary. This change is smaller than the existing daily fluctuations caused by flow conditions. The ETM suspends nutrients in the estuary, which are then distributed by tides and currents in the river system. Any fluctuation in the location of the ETM that may result from the Project is not expected to affect the tidal influences and currents that distribute nutrients throughout the estuary. The effect of the potential shift of the ETM on distribution of nutrients in the estuary is expected to be so small that it cannot be measured.

6.2.1.6 Bathymetric Changes

The 3-foot lowering of the channel bathymetry will occur in 56 percent of the navigation channel. This is not expected to directly impair habitat-forming processes because the increase in water depth will be limited to the area of the navigation channel that will add 3 feet to the water column type of habitat. Flowlane disposal will occur in water column habitat. It will not have an effect on habitat-forming processes for any of the habitat types. The potential effects of changes in bathymetry on habitat-forming processes in tidal marsh and swamp and shallow water and flats habitat have been addressed earlier in the discussions of suspended sediment increases, side-slope adjustments, and salinity increases. Habitat opportunity, as defined by Bottom et al. (2001), considers water depth and velocity conditions that provide favorable habitat for juvenile salmonids. Using this definition of habitat opportunity, modeling results are nearly identical for base and plan, indicating that the proposed actions will not have an impact on habitat opportunity as it relates to water depth in the estuary (see Section 6.1.27, Bathymetry and Turbidity). Shoreline disposal will occur in areas where salmonid habitat is not present and will not affect habitat-forming processes (see Section 6.1.9, Shallow Water and Flats Habitat). Finally, bathymetric changes caused by the Project include a potential up to a 0.18-foot decrease in water surface elevation between RM 80 and 146. This is not anticipated to affect habitat-forming processes (see Section 6.1.7, 3, Changes in Water Surface Elevation Resulting from Hydrodynamic Changes).

6.2.1.7 Conclusion

Modeling performed for the proposed Project, as well as analysis provided in this document, indicate that there will not be any significant effect on habitat-forming processes as a result of the proposed Project. The Corps is proposing monitoring to verify this conclusion (see Section 7.3, Monitoring Actions).

6.2.2 Habitat Types Pathway

Sections 6.1.8 through 6.1.10 discussed potential changes to the three primary habitats of juvenile salmonids in the lower Columbia River. The following potential changes to these habitat areas were identified:

- Side-slope adjustments associated with the Project may cause a shift in the location of shallow water habitat-forming processes in areas where the navigation channel is adjacent to previous shoreline disposal sites (see Section 6.2.1.2, Side-Slope Adjustment).

- Shoreline disposal could potentially disturb and shift the location of shallow water habitat at three proposed deposit sites: Sand Island, Miller Sands, and Skamokawa Beach (see Figure 3-4 and Appendix C).

- Water column habitat will be directly affected by the increased depth (approximately 3 feet) of the water column within a portion of the navigation channel in the action area (see Section 6.2.1.6 Bathymetric Changes).

- Water column habitat may be affected by drilling and blasting activities

- Water clarity may be reduced temporarily by the action of the dredge head on the bottom of the navigation channel and by flowlane disposal of dredged material (see Section 6.2.1.1, Increased Suspended Sediment, and Section 6.2.1.3, Increased Turbidity).

- Proposed dredging timelines are consistent with the existing BO for O&M dredging because dredging occurs in areas where salmon are not present at depths greater than 20 feet (see Table 3-1).

As noted, several of these potential effects are discussed in Section 6.2.1, Habitat-Forming Processes Pathway. The possible effects on the Habitat Types Pathway from the other indicator changes are discussed in the following subsections.

6.2.2.1 Shoreline Disposal

While the three identified shoreline disposal sites have the potential to affect salmonid habitat areas, an assessment of the sites concluded that they do not contain many of the important habitat features that shallow water habitats used by salmon typically include, such as low velocity, vegetation, and food sources. These areas likely provide a corridor for migrating salmonids, and, consequently, there is some potential effect from this action.

6.2.2.2 Drilling and Blasting

Blasting will be done during the preferred in-water work window. This is the period when salmonids abundance is lowest and will minimize impacts to the listed stocks. In addition, since there may be some fish in the river, the blasting plan will be designed to further minimize any impacts by keeping over pressures above the blast zone to less than 10 psi. This level is generally believed to be below the level at which salmonids would be adversely affected. A state approved plan for blasting will also be developed to further minimize impacts. Based on the above, the potential impacts to water column habitat will be minimized.

6.2.2.3 Timing Windows

Dredging and disposal during construction will be done year-round for 2 years. Although this is outside of the normal November 1 through February 28 in-water work period for the lower Columbia River it is not anticipated that it will have a significant effects on listed salmonids. Salmonids normally do not occur to any extent in the areas being dredged or the disposal sites (except the three shoreline sites). Juvenile salmonids normally migrate along the channel margins using the side slopes as structure

(Carlson et al., 2001). They occur primarily at depths less than 20 feet and so would not be expected to be affected by dredging and disposal operations. Although they can occur near the three shoreline disposal sites, these sites, are highly erosive and do not provide much, if any, habitat. Based on the above, potential impacts associated with project timing will be minimized.

6.2.2.4 Conclusion

Although none of the identified indicator changes discussed above is believed to have a measurable effect on existing habitat types, the Corps is proposing to implement compliance measures to ensure effects will be minimized and will also monitor to confirm this conclusion.

6.2.3 Habitat Primary Productivity Pathway

Sections 6.1.11 through 6.1.16 discussed potential changes in the six factors that are important to primary productivity within salmonid habitat. The following potential changes to primary productivity were identified:

- Short-term reductions in light may result in localized, short-term reductions in photosynthesis by benthic plants and phytoplankton.

- Change in salinity intrusion may affect the location of resident phytoplankton productivity, the location where imported freshwater phytoplankton contact intolerable salinity extremes, and the location of benthic algae productivity. These productivity changes are anticipated to be undetectable (see Section 6.1.14, Resident Phytoplankton Production, and 6.1.15, Benthic Algae Production).

The potential effects to the Habitat Primary Productivity Pathway resulting from the identified indicator changes are discussed in the following subsections.

6.2.3.1 Light Reduction

While short-term reductions in light may result in short-term reductions in photosynthesis by benthic plants and phytoplankton, these changes are not of sufficient duration to result in a loss of vegetation or measurable biomass production. The ephemeral and transient nature of the activities suggests that a reduction in light penetration would occur for only very short periods of time. In addition, the reductions will occur primarily in deep water areas that do not support large amounts of vegetation other than phytoplankton.

6.2.3.2 Salinity Change

No change in type or quantity of imported phytoplankton within the system is anticipated. In addition, while resident phytoplankton will expand its range in correlation with any upstream expansion of salinity, this effect on phytoplankton will not be measurable because the upstream expansion of salinity is not anticipated to be measurable. There may be a small upstream expansion of benthic algae production, but this is difficult to determine because a myriad of diatom species that make up the flora are euryhaline. None of these slight changes would have a measurable effect on primary productivity within the system.

6.2.3.3 Conclusion

No changes to primary productivity are anticipated as a result of the proposed Project.

6.2.4 Food Web Pathway

Sections 6.1.17 through 6.1.24 discussed potential changes in eight relevant components of the food web in the lower Columbia River. The following potential changes to those eight food web components were identified:

- Limited removal and burying of deposit feeders, suspension/deposit feeders, and suspension feeders will occur in portions of the navigation channel and deep water areas.
- Dredging and disposal actions will result in loss of adult and juvenile mobile macroinvertebrates.
- There may be a slight upstream shift in the ETM, which would be accompanied by a slight shift in the focus of resident and imported microdetritus food web input (see Section 6.2.3.2, Salinity Change).

Potential changes resulting from the shift in the ETM are discussed in Section 6.1.5, Salinity. Potential changes to Dungeness crab populations are discussed below.

6.2.4.1 Effect on Deposit Feeders, Suspension/Deposit Feeders, and Suspension Feeders

Removal and burial effects on these organisms are expected to be relatively short-lived, with dredge and disposal areas being recolonized. These organisms occur in low densities in the navigation channel because the sand waves create unstable habitat conditions. In these and other areas of the river, densities fluctuate as a result of constantly changing environmental conditions. No changes to these organisms are anticipated in shallow water areas, side channels, or embayments, which are the important locations for salmonid feeding opportunities. Regardless, the Corps' proposed monitoring program will include a post-project survey of ecosystem conditions that will address these organisms in shallow water areas.

6.2.4.2 Effect on Mobile Macroinvertebrates

Some mortality of mobile macroinvertebrates by dredging and disposal operations will occur; however, this mortality is expected to have an insignificant effect on these populations in either the estuary or the river mouth. Mobile macroinvertebrates are adapted to respond rapidly to disturbances, and to re-colonize areas following these disturbances. Mobile macroinvertebrates can be an important food item for salmonids in estuaries. Changes in mobile macroinvertebrate populations resulting from project actions are not anticipated to be large enough to affect the salmonid food web.

6.2.4.3 Conclusion

No significant changes to the food web are anticipated as a result of the proposed Project.

6.2.5 Growth Pathway

Sections 6.1.25 through 6.1.30 discuss potential changes in six important factors that can influence the growth of salmonids. No significant potential changes to those six growth factors were identified.

6.2.5.1 Conclusion

No changes to the Growth Pathway are anticipated as a result of the proposed Project.

6.2.6 Survival Pathway

Sections 6.1.31 through 6.1.38 discuss potential changes in eight important factors that can influence the survival of salmonids. The following potential change to those eight important survival factors was identified:

- A turbidity plume associated with dredging and disposal activities could increase salmonid predation. The potential for changes to the turbidity indicator is discussed below.

6.2.6.1 Turbidity Increase

Sediment increases are likely to be localized in deeper water and sandy beach areas and will be of short duration. In particular for juvenile salmonids, the turbidity increase is unlikely to affect survival because juveniles do not use these areas.

6.2.6.2 Conclusion

No changes to the Survival Pathway are anticipated as a result of the proposed Project.

6.3 Project Effects on Listed Species and their Habitat

This section uses the conceptual model to evaluate how identified effects to the ecosystem (as determined from the pathways analysis in Section 6.2) may affect the listed and candidate salmonid species (short-term effects). It also addresses potential effects on the Columbia River ecosystem over the 50-year life of the Project (long-term effects).

6.3.1 Potential Short-Term Ecosystem Effects

The following are the potential ecosystem pathway effects that have been identified through application of the conceptual model:

- There may be a temporary loss of shallow water habitat associated with dredge material disposal at three shoreline disposal sites.

- Water column habitat may be affected by drilling and blasting activities.

- Proposed dredging timelines are consistent with the existing BO for O&M dredging. In addition, dredging will occur in areas that salmonids do not use at depths greater than 20 feet.

6.3.2 Shoreline Disposal of Dredge Material

One shoreline disposal site is located within the riverine reach at Sand Island (O-86.2). The site is a beach nourishment site intended for disposal during both construction and maintenance dredging. Two shoreline disposal sites are located within the estuarine portion of the action area – Miller Sands Island, which is located within the estuary at O-23.5, and Skamokawa Beach, which is located at W-33.4.

A narrow band of shallow water will be affected by disposal at these shoreline disposal sites. However, because there is so little actual habitat within the potential disturbance areas for these three disposal sites, there is very little potential for actual effects on salmonids. To eliminate even this slight potential, the Corps is proposing impact minimization measures that should ensure there be no actual impact to salmonids. These are discussed in Section 7.4, Compliance Actions.

6.3.2.1 Drilling and Blasting

The proposed compliance measures associated with drilling and blasting activities are anticipated to be adequate to prevent effects on listed species. Monitoring will be performed to ensure that this conclusion is accurate. If impacts to listed species are identified by monitoring, then appropriate compensation will be negotiated with the Services (see Section 9).

6.3.2.2 Timing Windows

The compliance measures associated with the proposed project timing are anticipated to be adequate to prevent effects on listed species. Monitoring will be performed to ensure that this conclusion is accurate. If impacts to listed species are identified by monitoring, then appropriate compensation will be negotiated with the Services (see Section 9).

6.3.3 Potential Long-Term Ecosystem Effects

During the reconsultation process, concerns have been identified regarding potential long-term effects of the Project. These have centered on minor changes that may be caused by Project actions that are not detectable in the short term, but may affect listed salmonid habitat over the next 50 years. This could also include ecosystem effects that are not identifiable, given the current understanding of the ecosystem. Areas for which concern has been expressed during this reconsultation include those related to the ETM, formation and preservation of tidal marsh and swamp habitats, habitat opportunity changes in isolated geographic areas, and elimination of connectivity between habitats relied on by juvenile salmonids.

The Corps recognizes that this is an issue that needs to be addressed by this BA. Section 7 contains actions to gather information that will be used to address effects that are not detectable in the short-term (see Table 7-1, Monitoring Actions Associated with Dredging and Disposal). Section 8.3 contains actions that will address ecosystem research that is aimed at advancing the knowledge base for the recovery of the listed salmonids. This research may result in identification of effects that are not currently understood, given the current knowledge of the ecosystem.

6.3.4 Conclusion

None of the identified potential effects are anticipated to measurably affect salmonids; however, there is uncertainty associated with ecosystem processes that warrant implementing specific impact minimization, monitoring, and research actions (see Section 7.3, Monitoring Actions; Section 7.4, Compliance Actions; and Section 8.3, Ecosystem Research Actions).

6.4 Activities Not Included in this BA

Although 11.6 miles of the Willamette River are included in the channel deepening project authorized by Congress, deepening in the Willamette River channel is not analyzed in this BA because intervening events have placed Willamette channel deepening into a separate process and time line.

Concerns over sediment contamination and uncertainty regarding the scope and timing of remedial investigations and actions in the Willamette River led the Sponsor Ports to ask that the Corps delay deepening work on the Willamette channel. Subsequently, EPA designated Portland Harbor, which includes a 5.5-mile portion of the navigation channel, as a federal Superfund cleanup site. The Superfund listing only increases the uncertainty surrounding the timing of any channel improvements in the Willamette River. These intervening events make it impossible to meaningfully analyze potential effects on listed species or critical habitat at this time.

Cleanup under the Superfund program will involve extensive study of the area, evaluation of alternatives, and public involvement in the selection of a final cleanup plan. The final cleanup plan selected by EPA may result in changes to the previously proposed channel improvements for the Willamette River – changes that cannot be anticipated at this time. Any improvements to the channel in the Willamette River will therefore take place under conditions different from those found today – i.e., conditions reflecting the Superfund cleanup. Accordingly, the Sponsor Ports and the Corps will not move forward on deepening in the Willamette River channel until plans are fully in place for the necessary remediation. Further, once remediation plans are in place, the Corps plans on re-evaluating the costs and benefits of the Willamette River reach to ensure that deepening it is still justified. Finally, at such time as the Sponsor Ports and the Corps may proceed with channel improvements activities for the Willamette River, the Corps will review the project through a separate ESA consultation process.

Similarly, with the exception of berth deepening, future development of other port facilities is not analyzed here because such development will be caused by regional market factors such as commodity demand, not by channel deepening. The Corps' NEPA analysis supports the finding that berth deepening constitutes the only anticipated indirect effect of channel deepening.

The FEIS found that channel deepening in itself will not induce additional ship traffic – or contribute to development of additional ports or port facilities (see Corps, 1999a, Section 6.8, Socio-Economic Resources and Section 6.9, Secondary Impacts). This conclusion is consistent with historical vessel traffic trends on the Columbia River and with the market forces that drive port facility development.

Although channel deepening is critical to the Pacific Northwest region's ability to competitively handle the projected increase in cargo, deepening is not dependent on, and is not likely in and of itself to cause development of, additional marine terminal facilities. Separate studies forecast that cargo volumes transiting the Portland/Vancouver harbors will double over the next 20 years (ICF Kaiser et al., 1999), while seaport volumes at the Washington Columbia River ports will increase by 38 percent over the same period (ICF Kaiser, et al., 1999). These are unconstrained projections of cargo demand, which make no assumptions about channel depth or other infrastructure improvements.

The lower Columbia River ports have no plans to build new marine terminals to accommodate or respond to channel deepening. Similarly, there are no known plans by private developers to add terminal capacity as a result of, or contingent on the channel deepening. Sufficient overcapacity exists at the Port of Portland's Terminal 6 container terminal and at the existing grain elevators at the lower Columbia River ports to accommodate increased cargo volumes without requiring immediate new development.

Channel deepening is not likely to induce development of additional ports or port facilities. Future additions to Columbia River marine terminal capacity will be driven by market demand. "More or less demand for goods shipped from the lower Columbia River ports would occur with or without a deeper channel" (Corps, 1999a). However, "a deeper channel would help maintain the competitive position of the Columbia River ports" (Corps, 1999a) by allowing more cargo to be carried on about the same total number of vessels that call at these ports today. Any future terminal development or expansion undertaken to accommodate increased cargo volumes caused by market demand would be subject to separate environmental analysis and regulatory approvals.

7 ACTIONS ASSOCIATED WITH DREDGING AND DISPOSAL [ESA SECTION 7(A)(2)]

7.1 Introduction

Substantial effort by personnel from the Corps, the Services, and independent scientists has been directed at identifying the interrelationship among pertinent physical factors, habitat, and salmonids in the Columbia River and estuary. Knowledge of these specific interrelationships is integral to the determination of project-related effects on listed salmonids and other resources. To ensure that the best available science was used to document listed salmonid resources and potential project-related impacts, SEI convened a panel of independent scientists knowledgeable of the resources issues. The SEI panel participated in a series of meetings facilitated by SEI to discuss and evaluate scientific and technical issues related to the project. Curricula vitae for the panel members are included in Appendix A.

A Biological Review Team (BRT) made up of federal agency representatives was formed for the informal consultation. The BRT met at least weekly for approximately 8 months to address biological concerns associated with the BA process. The BRT served as a catalyst for identification of ecosystem restoration measures and research actions to further resource recovery and baseline information on ESA salmonids and their habitat.

Previous sections in this BA have dealt with identification of resources, the relationship between these resources and physical parameters, and ESA salmonid habitat, including critical habitat. Discussions have also dealt with project-related effects, either directly on listed ESUs or indirectly on their habitat, prey resources, or physical parameters that influence their use of the estuary and river.

This section establishes a monitoring plan to validate the nature and extent of expected effects. The information obtained through the monitoring plan described in this section will be used as input to the adaptive management framework described in Section 9. Additionally, there is a lower river/estuary restoration and monitoring program designed to restore habitat function as well as inform about certain restoration techniques (see Section 8, Table 8-1).

An Adaptive Management Team (AMT), made up of federal agency representatives, has been established to hear research and monitoring results and then render management decisions on adapting project implementation actions to counter or negate adverse effects. The AMT and proposed monitoring actions are intended to validate the conclusions of the BA, help minimize take of listed species, and ensure that proposed activities will not jeopardize listed species or adversely modify designated critical habitat [ESA Section 7(a)(2)]. The proposed monitoring plan, on which the AMT will rely for appropriate data, will monitor to address uncertainty and risk related to potential project effects over the long term and to validate assumptions used in analyzing project effects (see Table 7-1).

The Corps has identified two types of actions to address the conservation needs for the Project associated with effects of dredging and disposal: monitoring actions and compliance actions. These actions are described in the following sections.

7.2 Risk and Uncertainty

The SEI scientific panel identified risk and uncertainty as necessary components of scientific and management decisions. Risk and uncertainty were discussed as part of the BRT meetings. From these discussions, areas of risk and uncertainty associated with the indicators in the conceptual model were identified. These are presented in a conceptual framework outlined in Table 7-1. In addition, the BRT developed the following definitions of risk and uncertainty.

Uncertainty is an inverse indicator of confidence in one's ability to predict a change in a physical or biological parameter. Uncertainty is related to general and/or site-specific knowledge about a parameter and the methods available to predict change. Uncertainty would be higher for parameters for which little or no data are available than it would be for parameters with abundant available data. Uncertainty would also be higher for parameters for which there are no established methods for predicting change than for parameters that have empirical relationships or models to predict change. The highest degree of uncertainty would be for parameters with no available data and only judgment as a means to predict changes. The lowest uncertainty would be for parameters with abundant data and established numerical models to predict change.

Risk represents the potential threat to the health or survival of salmonids caused by changes in physical or biological parameters. Risk is a function of the sensitivity of salmonids, or their habitat, to a change in a parameter. The more sensitive salmonids are to a parameter and the larger the potential change, the greater the risk to salmonids. The greatest risk to salmonids would come from large changes to highly sensitive parameters, while small changes to low sensitivity parameters would produce the lowest risk.

Note that the concept of uncertainty and risk here is different from the concept of effects. There can be high uncertainty without concluding that an adverse effect is likely. A discussion of the monitoring scenarios shown in Figure 7-1 follows:

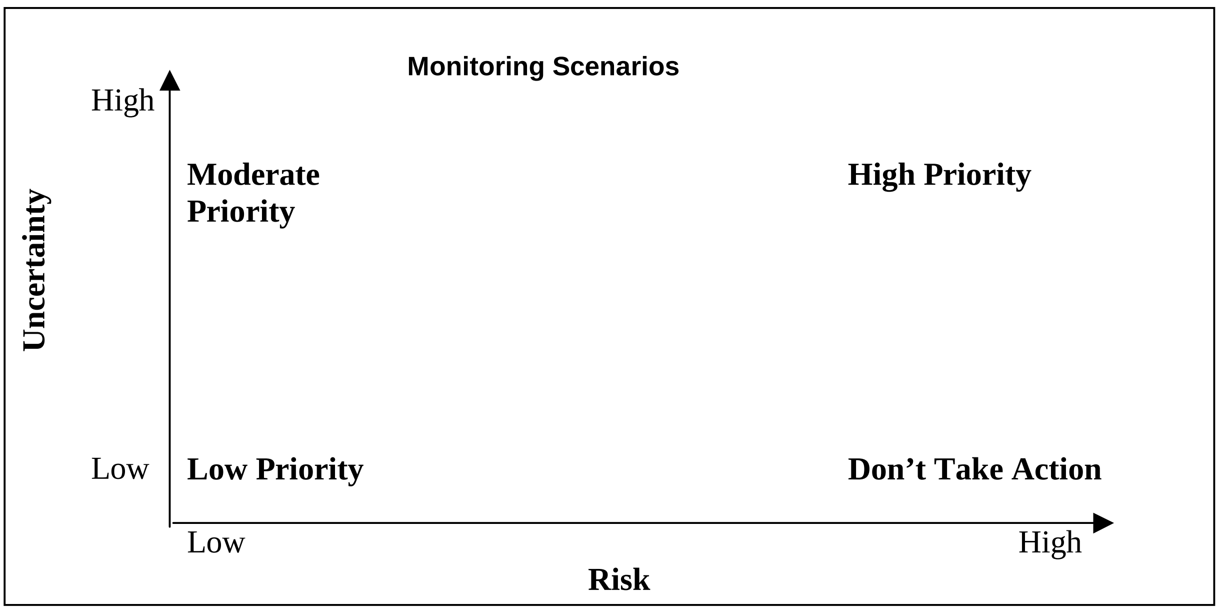


Figure 7-1: Risk Monitoring Scenarios

The purpose of assigning relative risk and uncertainty to each indicator was to evaluate whether any indicator had a high risk coupled with a low uncertainty. In other words, if the analysis showed a high risk with much known (certainty) to a given indicator, this combination would warrant no action being taken. The next combination of risk and uncertainty that would have a high priority for monitoring would be where the analysis found a medium to high risk and medium to high uncertainty. No indicators fit either of these two categories. Low priority monitoring actions are those that have low to medium risk and low to medium uncertainty. Suspended sediments, salinity, velocity, feeding habitat opportunity, refugia, and suspended solids fit this category. Although these had a low priority for monitoring, Monitoring Action 1 and Monitoring Action 4 will provide information about these indicators and will be included.

The last category for monitoring has a moderate priority and would have a combined low to medium risk and medium to high uncertainty because not much data are available, or there are no established methods for predicting change. Many of the indicators fell into this category. The monitoring actions were then developed to assess the indicators that the BRT thought were most important to the listed stocks, centered around a habitat and ecosystem approach that assesses type, function, and value to the listed stocks.

Table 7-1 presents a summary of the risks and uncertainties associated with the assessment of effects for the Project identified by the SEI Panel and the BRT. The table summarizes for each indicator the level of uncertainty and risk associated with the analysis.

For example, the table notes that the level of uncertainty for suspended sediment is low because there are ample data and the analysis was performed using an empirical method. The risk associated with this parameter is low because salmonids are not sensitive to changes in suspended sediments and the model predicted no, or a very small, change.

Table 7-1: Risk and Uncertainty Conceptual Framework

Pathway	**Indicator**	Uncertainty	Risk
Habitat-Forming Processes	Suspended sediment	**L** Lots of available data Empirical method	**L** Sensitivity very low No to small change
	Bedload (Main Channel)	**M** Limited data Empirical equation	**L** Sensitivity low Change none
	Woody debris	**H** No data Professional judgment	**L+** Sensitivity low to medium No change
	Turbidity	**M+** Limited data Judgment, conceptual model	**L** Sensitivity low Small change
	Salinity	**L** Limited to abundant data Strong scientific methods	**L+** Sensitivity moderate Small change
	Accretion/Erosion (Shallows)	**M** Limited data Empirical	**L** Sensitivity low No to small change
	Bathymetry (Channel)	**L** Abundant data Models strong scientific method	**M-** Sensitivity low Measurable change
Habitat Type	Tidal Marsh and Swamp Habitat	**M** Limited data Conceptual model	**L+** Sensitivity moderate No to small change

Pathway	Indicator	Uncertainty	Risk
	Shallow Water and Flats Habitat	**M** Limited data Empirical	**M-L+** Sensitivity moderate to high Small change
	Water Column Habitat	**M** Limited data Judgment and empirical	**L** Sensitivity low None to small change
Habitat Primary Productivity	Light	**M** Limited data Conceptual model	**L** Sensitivity low No change
	Nutrients	**M+** Limited data Professional judgment	**L** Sensitivity low No to small change
	Imported Phytoplankton Production	**M** Limited data Professional judgment	**L** Sensitivity low Small change
	Resident Phytoplankton Production	**M** Limited data Professional judgment	**L** Sensitivity low Small change
	Benthic Algae Production	**H** Limited data Professional judgment	**L+** Sensitivity low No to small change
	Tidal Marsh and Swamp Production	**M** Limited data Conceptual model	**L+** Medium sensitivity No to small change
Food Web	Deposit Feeders (Channel Bottom)	**M** Limited data Conceptual model	**L** Sensitivity low Small change
	Deposit Feeders (Side Channels)	**M** Limited information Judgment-empirical Conceptual model	**M** Sensitivity medium No to measurable change
	Mobile Macro-invertebrates	**M** Limited data Judgment-empirical	**L** Sensitivity low No change
	Insects (Side Channel, Tidal Marsh)	**H** None to limited data Judgment	**M** Sensitivity medium Small change
	Suspension/Deposit Feeders	**M** Limited information Judgment - empirical Conceptual Model	**M** Sensitivity medium Measurable change

Pathway	Indicator	Uncertainty	Risk
	Suspension Feeders (Side Channel)	**M** Limited information Judgement - empirical Conceptual Model	**M** Sensitivity medium No to measurable change
	Tidal Marsh Macrodetritus	**H** No available data Professional judgment	**L+** Sensitivity medium Small change
	Resident Microdetritus	**H** No available data Professional judgment	**L+** Sensitivity low Small change
	Imported Microdetritus	**M** Limited data Empirical	**L+** Sensitivity medium No change
Growth	Habitat Complexity, Connectivity, Conveyance	**L+** Limited data Strong scientific methods	**M** Sensitivity high No to small change
	Velocity Field	**L** Limited data Modeled data 2x	**L** Sensitivity low No to measurable change
	Bathymetry and Turbidity	**H** Limited data to no data Professional judgment	**M** Sensitivity medium to high No to little change
	Feeding Habitat Opportunity	**L** Limited data Some modeling	**L+** Sensitivity medium to high No to little change
	Refugia	**L** Limited data Conceptual model	**L+** Sensitivity High No change
	Habitat-Specific Food Availability	**M** No to little data Conceptual model	**M** Sensitivity high Small change
Survival	Contaminants	**M** Lots of data/limited Empirical methods/ professional judgment	**M** Medium sensitivity Change measurable
	Disease	**L** Much data Some empirical	**M-** Sensitivity high No change
	Suspended Solids	**L** Lots of data Empirical method	**L** Sensitivity very low No to small change

Pathway	Indicator	Uncertainty	Risk
	Stranding	**L** Much data Empirical method	**M** Sensitivity high Small change
	Temperature and Salinity Extremes	**L+** Some data Modeling temp. data literature	**M** Sensitivity high No to small change
	Turbidity	**M+** Limited data Judgment Conceptual Model	**L** Sensitivity low Small change
	Predation	**M** Limited data Some studies	**M** Sensitivity high No to low change
	Entrainment	**L** Abundant data Empirical method	**M** Sensitivity high No change

7.3 Monitoring Actions

The proposed monitoring actions will help to ensure that the conclusions of the Project analysis regarding minor effects on habitat and individuals in Section 6 are correct. The monitoring actions proposed are for indicators where the levels of uncertainty and risk from project effects warrant gathering additional information. It should be noted that these levels of risk were not high enough to alter the conclusions in Section 6 concerning the effects on the listed and candidate salmonid species, but still of a level to warrant verification through monitoring. This includes potential effects on indicators related to potential for take of individuals of the listed and candidate salmonid species, as well as their habitat.

Monitoring actions proposed for the Project are summarized in Table 7-1. The contents of the summary table include:

- Conceptual model indicator(s) addressed by each monitoring action
- Description of the monitoring task to be implemented
- Technical justification for each of the monitoring tasks
- Relative uncertainty and risk from project effects identified by the Corps, NMFS, and USFWS and the analysis for each of the indicator(s)
- Duration of the monitoring proposed for each task
- Analysis of monitoring data for each monitoring task

The pathways and indicators shown Table 7-2 apply to the monitoring actions listed in Table 7-3.

Table 7-2: Pathways and Indicators Addressed by Project Monitoring Actions

Pathways	Indicators	Monitoring Actions
Habitat-forming processes	Bedload *(see Section 6.1.2.3)*	Monitoring Action 1
	Salinity *(see Section 6.1.5.3)*	Monitoring Action 1
	Accretion/Erosion (*see Section 6.1.6.1)*	Monitoring Action 3
	Bathymetry *(see Section 6.1.7.4)*	Monitoring Action 3
Habitat type	Tidal marsh and swamp habitat *(see Sections 6.1.8.2 and 6.1.16.2)*	Monitoring Action 4
	Shallow water and flats habitat *(see Section 6.1.9.3)*	Monitoring Action 3
Food Web	Insects *(see Section 6.1.19.2)*	Monitoring Action 4
	Suspension/deposit feeders *(see Sections 6.1.17, 6.1.20, and 6.1.21)*	Monitoring Action 4
	Tidal marsh macrodetritus *(see Section 6.1.22.2)*	Monitoring Action 4
Growth	Habitat complexity, connectivity, and conveyance *(see Section 6.1.25.1)*	Monitoring Action 1
	Velocity field *(see Section 6.1.26.2)*	Monitoring Action 1
	Feeding habitat opportunity (*see Section 6.1.28.3)*	Monitoring Action 1
	Refugia *(see Section 6.1.29.3)*	Monitoring Action 4
	Habitat-specific food availability (*see Section 6.1.30.2)*	Monitoring Action 4
Survival	Contaminants *(see Section 6.1.31.2)*	Monitoring Action 5
	Stranding *(see Section 6.1.34.2)*	Monitoring Action 6

In addition to the indicators listed in Table 7-2, monitoring actions will obtain information on water surface elevations in the estuary and dredging volumes.

Data obtained from the monitoring provide ongoing evaluation and verification of conclusions summarized in Section 6. The data will also provide information about salmonid use of and interactions within the lower Columbia River ecosystem.

Table 7-3 identifies the indicators, tasks, justification, uncertainty, duration, and data analysis for each monitoring action. Monitoring Action 1 will rely on research scientists to identify baseline conditions and then determine if there are significant changes arising from project implementation. Monitoring Actions 2, 3, 4, 5, and 6 will rely on personnel from the Corps, NMFS, or their contractors to compile the necessary information and conduct the appropriate analyses. Each entity responsible for a specific monitoring action is tasked to provide annual reports and participate in the annual AMT meetings.

These monitoring actions will be coordinated with other compliance, restoration, and research actions to be undertaken for the lower Columbia River. Section 9 describes the adaptive management approach that will be implemented by the Corps.

7.4 Compliance Actions

Compliance actions are those actions that will be taken during the implementation of project actions to avoid or minimize potential effects on listed and candidate salmonid species. These compliance measures prescribe safeguards, techniques, and guidelines that will be followed to avoid or minimize take.
Table 7-4 addresses BMPs for project disposal and dredging actions, as well as timing restrictions associated with these actions. Further, the Corps proposes to use compliance actions identified in Tables 7-5 and 7-6, to ensure that the proposed Project minimizes or avoids take of individual listed or candidate salmonid species or their habitat. These compliance actions have been developed over time through the Corps' dredging program; they are considered to represent the best management practices for dredging and disposal to minimize any adverse effect to listed species or their habitat. These actions will be monitored by onsite inspection under established quality assurance processes. If the inspection identifies new information that potentially warrants a change, that information will be reported to the adaptive management team (see Section 9) for consideration of changes to the compliance measures.

Table 7-3: ESA Sec. 7(a)(2) Monitoring Actions Associated with Dredging and Disposal

Monitoring Action Number	Indicator	Monitoring Task	Justification	Uncertainty And Risk[1]	Duration	Data Analysis	Trigger For Management Changes
MA-1	Salinity, velocity, water surface, habitat complexity, connectivity, and conveyance, and habitat opportunity.	The Corps will maintain three hydraulic monitoring stations, one downstream of Astoria, one in Grays Bay, and one in Cathlamet Bay. Parameters measured would include salinity, water surface, and water temperature.	Physical changes related to channel deepening are expected to be small and concentrated near the navigation channel.	Salinity L,L+; velocity L,L; bathymetry L,M-; habitat complexity, connectivity, and conveyance L+, M;	7 years: 2 years before, 2 years during, and 3 years after construction	An analysis would be conducted to determine pre- and post-project relationships among flow, tide, salinity, water surface, and temperature.	Post-project data exceeds defined threshold values. Determine if task should continue and what funding source is appropriate.
MA-2	Dredging volume, bedload.	Annual dredging volumes, construction and O&M.	To ensure scale of the project does not change.	Bedload M, L	Life of the project.	Actual volumes will be compared to predicted.	Dredging volumes exceed capacity of the disposal plan.
MA-3	Accretion/erosion, bathymetry (main channel).	Main channel bathymetric surveys throughout project area.	Side-slope adjustments are expected to occur intermittently adjacent to the navigation channel.	Accretion/erosion M, L; bathymetry L, M-	7 years: 2 years before, 2 years during, and 3 years after construction	Bathymetric changes will be tracked to determine if habitat is altered.	Habitat alteration in main channel due to side-slope adjustment.
MA-4	Tidal marsh, swamp, flats, refugia, habitat complexity, connectivity and conveyance, suspension and deposit feeders, insects, macrodetritus and habitat specific food availability, juvenile salmonids in peripheral habitats and habitat opportunity.	Repeat estuary habitat surveys being conducted by NMFS (Bottom and Gore, 2001 proposal).	Identify if there is a change to habitat due to deepening.	Tidal marsh and swamp habitat M, L+; flats habitat M, M-L+; suspension/deposit feeders M, M; deposit feeders M, M; suspension feeders M, M; insects H, M: macrodetritus H, L+; habitat-specific food availability M, M; feeding habitat opportunity L, L+	One time survey conducted 3 years after completion of the deepening.	Habitat mapping from aerial photos and ground surveys.	Changes to individual habitat types that are based on defined threshold values. Determine need for other surveys.
MA-5	Contaminants	NMFS will review the SEDQUAL database to determine if there are areas that would require additional sampling. Review existing contaminants database using	Ensure that channel construction does not disturb undetected deposits of fine-grained material, potentially causing redistribution of	Contaminants M, M.	NMFS will review SEDQUAL data prior to construction; if additional samples are required they	Existing sediment data will be reviewed for the amount of fine-grained material. Chemical results will be compared to the	Detection of chemicals at concentrations that pose a risk to the health and/or survival of salmonids or trout.

Monitoring Action Number	Indicator	Monitoring Task	Justification	Uncertainty And Risk[1]	Duration	Data Analysis	Trigger For Management Changes
		NMFS guidelines or trigger values that are more protective of salmonids and trout. Provide notification during construction dredging to monitor for presence of fine-grained material – i..e., oily sheens. If found, dredging will cease in that location and additional testing will be conducted.	contaminants that could pose a risk to salmonids and trout.		would be obtained prior to construction. On-board observations would be conducted.	NMFS guideline for the protection of salmon.	
MA-6	Stranding	Field surveys will be made monthly at selected beaches (upper, mid, and lower river) during the April-August out-migration to measure the number of fish being stranded along beaches.	Identify if there is a change in stranding due to deepening.	Stranding L, M.	One year before deepening and 1 year after deepening.	Compare pre- and post-project stranding counts.	If there is an increase in the number of fish stranded, proposals would be developed and presented to decision makers.

[1]In this column "L"=low, "M"=medium, and "H"=high. A "+" sign means that the L, M, or H is of higher concern; a "-" means that the L, M, or H is of lower concern. The first L, M, or H after the indicator is the factor identified for uncertainty; the second L, M, or H after each indicator is the factor identified for risk. These factors were identified by the Corps, Sponsor Ports, NMFS, and USFWS (see Table 7-2).

Table 7-4: BMPs for Project Disposal and Dredging Actions

Construction Features	Type of Dredging	Timing
Navigation channel, including overdepth and overwidth dredging at depths greater than 20 feet	Hopper Pipeline Mechanical excavation	No timing windows No timing windows No timing windows
Turning basins at depths greater than 20 feet	Hopper Pipeline	No timing windows No timing windows
Rock removal with blasting	Mechanical excavation	November 1 to February 28
Rock removal at depths greater than 20 feet	Mechanical excavation	No timing windows
Berths	Mechanical excavation	November 1 to February 28
Ecosystem restoration features dredging at depths greater than 20 feet	Mechanical excavation Pipeline Hopper	No timing windows
Ecosystem restoration features dredging at depths less than 20 feet	Mechanical excavation Pipeline Hopper	November 1 to February 28

Table 7-5: Minimization Practices and Best Management Practices for Dredging

Monitoring Action Number	Indicator	Measure	Justification	Duration	Management Decision
Hopper Dredging					
CA-1	Entrainment (Survival) Benthic Invertebrates Deposit Feeders	Maintain dragheads in the substrate or no more than 3 feet off of the bottom with the dredge pumps running.	This restriction minimizes or eliminates entrainment of juvenile salmonids during normal dredging operations.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.
CA-2	Habitat Complexity Bathymetry & Turbidity Feeding Habitat Opportunity Suspension-Deposit Feeders Deposit Feeders Mobile Macroinvertabrates	Dredge in shallow water areas (less than 20 feet) only during the recommended ESA in-water work period for the Columbia River of November 1 until February 28.	Areas less than 20 feet deep are considered salmonid migratory habitat. Dredging or disposal in these areas could delay migration or reduce or eliminate food sources.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.
Pipeline Dredging					
CA-3	Entrainment (Survival) Benthic Invertebrates Deposit Feeders	Maintain cutterheads in the substrate or no more than 3 feet off of the bottom with the dredge pumps running.	This restriction minimizes or eliminates entrainment of juvenile salmonids during normal dredging operations.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.
CA-4	Habitat Complexity Bathymetry & Turbidity Feeding Habitat Opportunity Suspension-Deposit Feeders Deposit Feeders Mobile Macroinvertabrates	Dredge in shallow water areas (less than 20 feet) only during the recommended ESA in-water work period for the Columbia River of November 1 until February 28.	Areas less than 20 feet deep are considered salmonid migratory habitat. Dredging or disposal in these areas could delay migration or reduce or eliminate food sources.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.
General Provisions For All Dredging					
CA-5	Contaminants Water Column Habitat	The contractor will not release any trash, garbage, oil, grease, chemicals, or other contaminants into the waterway.	Protect water resources.	Life of contract or action.	If material is released, it will immediately be removed and the area restored to a condition approximating the adjacent undisturbed area. Contaminated ground will be excavated and removed, and the area restored as directed. Any in-water release will be immediately reported to the nearest U.S. Coast Guard Unit for appropriate response.
CA-6	NA	The contractor, where possible, will use or propose for use materials that may be considered environmentally friendly in that waste from such materials is not regulated as a hazardous waste or is not considered harmful to the environment. If hazardous wastes are generated, disposal of this material will be done in accordance with 40 CFR parts 260-272 and 49 CFR parts 100-177.	Dispose of hazardous waste.	Life of contract or action.	If material is released, it will immediately be removed and the area restored to a condition approximating the adjacent undisturbed area. Contaminated ground will be excavated and removed, and the area restored as directed. Any in-water release will be immediately reported to the nearest U.S. Coast Guard Unit for appropriate response.

Table 7-6: Best Management Practices for Disposal

Monitoring Action Number	Indicator	Measure	Justification	Duration	Management Decision
Flow Lane Disposal					
CA-7	Accretion/Erosion	Dispose of material in a manner that prevents mounding of the disposal material.	Spreading the material out will reduce the depth of the material on the bottom, which will reduce the impacts to fish and invertebrate populations.	Life of contract or action.	Maintain until new information becomes available that would warrant change.
CA-8	Bathymetry & Turbidity (Survival) Suspended Solids	Maintain discharge pipe of pipeline dredge at or below 20 feet of water depth during disposal.	This measure reduces the impact of disposal and increased suspended sediment and turbidity to migration juvenile salmonids, as they are believed to migrate principally in the upper 20 feet of the water column.	Continuous during disposal operations.	Maintain until new information becomes available that would warrant change.
Upland Disposal					
CA-9	Suspended Solids Turbidity (Survival) Bathymetry & Turbidity	Berm upland disposal sites to maximize the settling of fines in the runoff water.	This action reduces the potential for increasing suspended sediments and turbidity in the runoff water	Continuous during disposal operations.	Maintain until new information becomes available that would warrant change.
CA-10	Habitat Complexity, Connectivity Conveyance Insects Resident Macrodetritus, Microdetritus Large Woody Debris	Maintain 300-foot habitat buffer.	Maintains important habitat functions.	Life of contract or action.	Maintain until new information becomes available that would warrant a change.
Shoreline Disposal					
CA-11	Habitat Complexity Bathymetry & Turbidity Feeding Habitat Opportunity Suspension-Deposit Feeders Deposit Feeders Mobile Macroinvertabrates	Dispose of in shallow water areas (less than 20 feet) only during the recommended ESA inwater work period for the Columbia River of November 1 until February 28.	Areas less than 20 feet deep are considered salmonid migratory habitat, Dredging or disposal in these areas could delay migration or reduce or eliminate food sources.	Continuous during disposal operations.	Maintain until new information becomes available that would warrant change.
CA-12	Stranding	Grade disposal site to a slope of 10 to 15 percent, with no swales, to reduce the possibility of stranding of juvenile salmonids.	Ungraded slopes can provide conditions on the beach that will create small pools or flat slopes that strand juvenile salmonids when washed up by wave action.	Continuous during disposal operations.	Maintain until new information becomes available that would warrant change.
Ocean Disposal					
CA-13	N A	Dispose of in accordance with the site management and monitoring plan, which calls for a point dump placement of any material from the project during construction. The plan is to place any construction material in the southwest corner of the deep water site.	This action minimizes conflicts with users and impacts to ocean resources.	Continuous during dredging operations.	Maintain until new information becomes available that would warrant change.

Monitoring Action Number	Indicator	Measure	Justification	Duration	Management Decision
General Provisions For All Disposal					
CA-14	N A	Dispose of hazardous waste.	The contractor, where possible, will use or propose for use materials that may be considered environmentally friendly in that waste from such materials is not regulated as a hazardous waste or is not considered harmful to the environment. If hazardous wastes are generated, disposal of this material will be done in accordance with 40 CFR parts 260-272 and 49 CFR parts 100-177.	Life of contract or action.	If material is released, it will immediately be removed and the area restored to a condition approximating the adjacent undisturbed area. Contaminated ground will be excavated and removed, and the area restored as directed. Any in-water discharge will be immediately reported the nearest U.S. Coast Guard Unit for appropriate response.

8 ECOSYSTEM RESTORATION FEATURES AND RESEARCH ACTIONS [ESA SECTION 7(a)(1)]

8.1 Introduction

This section of the BA addresses additional ecosystem restoration and research actions added to the proposed action previously described. Pursuant to Section 7(a)(1) of the ESA, the federal agency, in this instance the Corps, "shall utilize their authorities in furtherance of the purposes of this chapter by carrying out programs for the conservation of endangered species and threatened species" [16 U.S.C. § 1536(a)(1)]. These actions are not measures intended to directly address take of listed species. However, they are measures that the Corps, with the assistance of the Services, has determined to be important to aid in the recovery of listed salmonids and, in some cases, address habitats that were the subject of much discussion and analysis throughout the reconsultation process.

The Corps proposes to implement ecosystem restoration features and research actions under Section 7(a)(1) of the ESA, as described in the following sections. The ecosystem restoration and research components proposed below will be cost-shared by the Sponsor Ports and are hereby considered part of the Project.

8.2 Ecosystem Restoration Features

Restoration features will be done by the Corps under this BA to create or improve salmonid habitat, specifically tidal marsh, swamp, and shallow water and flats habitat. In addition to the three original restoration features proposed in the 1999 FEIS, the Corps proposes to implement six more restoration features: Lois Island Embayment Habitat Restoration, Purple Loosestrife Control Program, Miller/Pillar Habitat Restoration, Tenasillahe Island Tidegate/Inlet Improvements (interim) and Dike Breach (long term), Cottonwood/Howard Island Columbia White-Tailed Deer Introduction, and Bachelor Slough Restoration. Interim actions at Tenasillahe Island are contingent on hydraulic engineering analyses demonstrating the feasibility of the proposed action and that no adverse impacts would be incurred by Columbia white-tailed deer. Implementation of the long-term action at Tenasillahe Island is contingent on delisting of Columbia white-tailed deer and determination that such actions are compatible with the purposes and goals of the refuge. The Bachelor Slough Restoration is contingent on securing easements from the Washington Department of Natural Resources (WDNR) and favorable sediment testing results. The Cottonwood/Howard Restoration is also contingent on acquisition of the site by the Sponsor Ports. Each of these actions is described below in Sections 8.2.1 through 8.2.6, followed by an analysis of their effects in Section 8.4.

8.2.1 Lois Island Embayment Habitat Restoration (RM 19)

The embayment between Lois and Mott Islands was dredged out during the World War II era to provide moorage for decommissioned naval ships. Prior to that time, the area was shallow subtidal and intertidal habitat with interspersed drainage channels. Lois and Mott Islands and South Tongue Point were formed from material dredged from this location. This ecosystem restoration feature will restore 389 acres of tidal marsh habitat.

Prior to construction of the embayment, the area contained intertidal mudflats and shallow subtidal flats plus a centralized channel 12 to 18 feet in depth running from northwest to southeast across much of the area. The average depth of the area was 5 to 6 feet with substantial area above zero feet in elevation (CREDDP, 1983: 1935 bathymetric map). Intertidal habitat would have ranged from -2 to 10 feet at this area of the Columbia River.

Post-construction of the moorage area, an embayment with rough dimensions of 3,750 feet by 4,375 feet was formed, with depths ranging from 12 to 30 feet and averaging 25 to 26 feet (CREDDP, 1983: 1958 bathymetric map). The eastern portion of the embayment is wider and juts slightly into Lois Island.

By 1982 (CREDDP, 1984: 1982 bathymetric map), depths in the embayment were approximately 21 feet on average, ranging from 18 to 24 feet. Lois and Mott Islands have developed narrow, fringing intertidal marsh habitat post-dredging on their interior shorelines bordering the embayment.

Given that the embayment filled in approximately 4 feet from 1958 to 1982, it is assumed that additional sedimentation has occurred between 1982 and 2001. Assuming that 3 feet of material has accumulated in that period, the embayment may currently average approximately 18 feet in depth or roughly 13 feet deeper than historical depths.

The restoration feature includes reconstruction of the area to historical elevations using dredged material from the Columbia River navigation channel. The shallow subtidal and intertidal habitats formerly present and proposed for restoration were more productive than the current, moderately deep, subtidal habitat. Gross benthic productivity for the fringing intertidal mudflat habitat at the embayment was 31 to 46 grams of carbon per square meter per year (CREDDP, 1984), which is comparable to other intertidal mudflat habitat in Cathlamet Bay. Tidal marsh plant standing crop at South Tongue Point was slightly above average for Cathlamet Bay (CREDDP, 1984).

Cates (1983) conducted fish sampling operations in the Tongue Point area in 1979 and again in 1981. Five of his seven sampling locations were within the Lois Island Embayment. These sampling locations were just beyond the intertidal marsh/mudflat interface on the periphery of the embayment. Thus, they are roughly comparable to the habitat conditions sought in the restoration action.

Cates (1983) captured 14 species, including four anadromous salmonids (chinook salmon, coho salmon, chum salmon, and cutthroat trout) in 1981, the year for which he provided the most detailed results. Chinook salmon were the most abundant salmonid captured in 1981 – 3,411 individuals of 3,619 salmonids captured (94 percent). Chinook juveniles were present in the area from March to late August, with peak abundance in May. Based on their size and period of occurrence, most of the chinook captured were considered to be subyearling fall chinook.

Chum salmon (147), coho salmon (61), and cutthroat trout (2) were of lesser abundance based on their beach seine results. Cates (1983) indicated that chum salmon captured were thought to be of wild origin as their occurrence preceded hatchery releases. He also captured juvenile chinook and coho salmon with coded wire tags at Tongue Point sampling locations. These included chinook salmon from the Klaskanie River, which empties into Youngs Bay immediately downstream of Astoria, and one coho salmon from the Grays River, Washington. These captures were an indication of upstream movement of chinook to the Tongue Point area for estuarine rearing and cross-river movement for coho.

Tongue Point and the embayment are used for a terminal salmon fishery, and commercial gill netting also occurs for sturgeon in the embayment. Sport fishing in the embayment is limited to a few boats fishing for sturgeon. Most sport fishing boats that launch from the nearby John Day boat ramp fish for sturgeon on the channelward side of Mott Island and off Tongue Point proper.

Emmett, et al. (1986), investigated benthic invertebrates in Cathlamet Bay, including the embayment between Lois and Mott Islands. They identified 28 benthic invertebrate species or groups (order, family, genus) as occurring within the embayment. Eight (*Cumacea*, *Corophium salmonis*, *Harpacticoida*, *Helidae* [larvae], *Insecta, Diptera* [adult], *Scottolana canadensis*, and *Chironomid* are preferred prey resources of juvenile salmonids. Their sampling occurred at depths of 16 to 20 feet. These species are also anticipated to be present in the intertidal mudflat and shallow subtidal habitat that would be present after restoration.

The area of the proposed restoration feature is approximately 389 acres. It runs from the southwest corner of the embayment off the John Day River mouth on a northwest-bearing line to the corner of the embayment south and east of Mott Island (CREDDP, 1983: see 1982 bathymetric map). The inner channel from John Day Point along South Tongue Point to Tongue Point would not be affected by restoration actions. The edge of the restoration area would be approximately 1,250 feet off South Tongue Point.

Restoration of the Lois Island Embayment would require approximately 8 mcy of material. It is estimated that 7 mcy from initial construction of the deepened channel could be placed at Lois-Mott Island embayment. The initial construction material would originate from the navigation channel between RM 3 and 30. The approximately 1 mcy of material needed to complete the restoration action would come from the navigation channel between RM 3 and 20. An estimated 2 to 3 years of O&M dredging would be required to complete the restoration action. Material dredged from the navigation channel would be transported via hopper dredge and initially placed in the upstream Tongue Point turning basin. No deep draft vessels currently call at Tongue Point because industrial facilities requiring their service have not been developed at this location. Consequently, placement of dredged material in the turning basin would not compromise vessel traffic. After placement of dredged material in the turning basin, a pipeline dredge would be used to transfer the material into the embayment to the target elevations. These target elevations would be predicated on the historical bathymetry of the area. The following actions will be taken as part of the Lois Island Embayment Habitat Restoration effort:

- Fund and implement construction effort
- Monitor post-construction benthic productivity and fish species composition and density on the restoration site and an adjacent control site

8.2.2 Purple Loosestrife Control Program

Purple loosestrife is an introduced exotic plant that is spreading throughout emergent tidal marshes in the Columbia River estuary. Native vegetation such as Lyngby’s sedge, tufted hair grass, wapato, and softstem bulrush are being displaced. Currently more than 10,000 acres of estuarine tidal marsh are infested, although the degree of infestation varies widely among locations. Large, dense stands, totaling perhaps 300 acres, are found at Karlson Island (RM 26), Miller Sands (RM 22.5), and North Wallace Island (RM 50). Loosestrife densities range from light (a few scattered plants) to moderate in other areas of the estuary. Given its history in other regions of North America, it is likely that loosestrife, if left unchecked, will dominate the emergent marsh habitat of the estuary to the exclusion of native vegetation. This would greatly reduce biological diversity and negatively affect most estuarine wildlife, including salmonids and other native fish, waterfowl, waterbirds, shorebirds, neotropical migrant birds, bald eagles, native mammals, and amphibians.

The goal of this program will be to eradicate the large stands and bring about a major reduction in loosestrife densities in emergent marsh in the estuary. An Integrated Pest Management approach will be used. The focus will be on biocontrol of dense stands, with thorough mapping and monitoring to determine the effectiveness of biocontrol in this tidal situation. Herbicides and mechanical methods will be used where plant densities are low to moderate. Rodeo, an EPA-registered herbicide approved for over-water application, would be used in conjunction with biocontrol and mechanical treatments to treat purple loosestrife infestations.

The following actions will be taken as part of the Purple Loosestrife Control ecosystem restoration feature:

- Project funding for field implementation of survey and control actions, including equipment and personnel expenses, for a 5-year effort

- All necessary coordination with local, state, and federal government agencies to accomplish the effort

- Provision of annual and final reports describing the nature and extent of the effort and results

8.2.3 Miller/Pillar Habitat Restoration (RM 26)

This ecosystem restoration feature is located between Miller Sands and Pillar Rock Islands in the Columbia River estuary (RM 25 to 26). More than 160 acres will be created. Natural processes are currently eroding material south of the navigation channel and redepositing the material in the navigation channel. This erosive action has been occurring since 1958 at an average annual rate of approximately 70,000 cubic yards. The erosion is affecting productive, shallow water and flats habitat (zero to 5.9 feet CRD) and converting the area to less productive, deep subtidal habitat (a minimum depth of 24.9 feet CRD) (Hinton, et al., 1995). Hinton, et al. (1995), conducted field investigations of benthic invertebrates, fish, and sediments at this location in 1992 and 1993. Their investigation compared resource values of the erosive area to adjacent shallow water and flats habitat.

Hinton, et al. (1995), determined that benthic invertebrate densities were significantly higher in the shallow water and flats habitat than in the proposed habitat restoration (erosive) area. The number of benthic invertebrate species was comparable between the erosive and natural site although species diversity was significantly higher in the shallow water and flats habitat. Overall, *Corophium salmonis* was the most abundant invertebrate in both study areas. *Corophium salmonis* is significantly denser in the shallow water and flats habitat compared to the deeper, erosive area. This species is an important forage resource for juvenile salmonids in the Columbia River estuary.

Eighteen species (17 fish, 1 shrimp) were collected in the two study sites (Hinton, et al., 1995). These included anadromous, marine, and freshwater fish species. Anadromous species collected included lamprey, white sturgeon, American shad, coho salmon, sockeye salmon, chinook salmon, and steelhead. Overall, the most abundant fish species in the proposed habitat restoration area were peamouth, prickly sculpin, starry flounder, and juvenile salmonids (zero to 692 individuals; all species combined). American shad, subyearling chinook, peamouth, threespine stickleback, and starry flounder were the most abundant fish in the shallow shallow water and flats habitat. Juvenile salmonids ranged from zero to 1,719 individuals collected per sampling period in the shallow water and flats habitat. Hinton, et al. (1995), reported that densities of subyearling chinook salmon in 1993 averaged 417 fish per acre in the proposed restoration area and 2,628 fish per acre in the shallow water and flats habitat.

Hinton, et al. (1995) reported that median sediment grain size was significantly larger in the restoration area (0.28 mm) than in the adjacent shallow water and flats habitat (0.22 mm). Mean percent silt/clay was higher in the shallow water and flats habitat than in the restoration area. Habitats within the proposed habitat restoration area appeared to be separated into at least two types and corresponded to the north and south sampling transects established by Hinton, et al. (1995). The south transect had significantly smaller sediment grain size and a significantly higher density of *Corophium*. Water depth was also less along the south transect, and NMFS estimated that bottom water velocities were also less along their southern transect. The southern transect is farthest from the navigation channel. The smaller sediment grain size, shallower depth, and lower velocity associated with the southern transect compared to the northern transect result in a more favorable substrate for *Corophium salmonis*.

Hinton, et al. (1995), stated that research results suggest that the habitat value of the proposed habitat restoration area could be enhanced by proper placement and stabilization of dredged material from the Columbia River to create habitat comparable to that in the adjacent shallow subtidal area. Placement of dredged material and its stabilization would create more favorable conditions for *Corophium salmonis* (e.g., reduced water velocities, decreased median grain size, increased percent silt/clay, and increased percent volatile solids). A subsequent increase in standing crop of *Corophium salmonis* should provide more food and rearing habitat for fishes, including juvenile anadromous fish (Hinton, et al., 1995).

Restoration of the erosive area to a productive, shallow water and flats habitat can be accomplished by placement of dredged material at the location to mimic historical depths. Assuming that the restoration area had a historical average depth of 2.95 feet CRD and currently has a minimum depth of 24.9 feet CRD, an increase of 22 feet of depth or 5,750,000 cubic yards of material would be required to retain historical subtidal depths. Dredged material placed at this location would be comparable to *in situ* materials. Dredged material retention will require the construction of pile dikes to reduce water velocities and maintain the desired substrate elevations. Five pile dikes, which make up the Miller-Pillar pile dike field, would be constructed during the initial construction phase of the channel deepening.

The dredged material would be obtained from the deepened navigation channel during subsequent maintenance dredging operations. This restoration feature would be phased during construction, with fill placed to the target depth, beginning at the upstream border and moving downstream. This would create shallow water habitat so that benefits to salmonids would begin accruing as soon as dredging materials become available. The time frame to accomplish this restoration depends on the volume of maintenance dredging material that accumulates in the navigation channel. Pipeline dredges would supply the material from adjacent bars, as the area is too shallow for placement via hopper dredge. Barging of material to the location for placement is physically feasible, although unlikely from a cost standpoint. River and tidal currents, in conjunction with wave action, are expected to re-establish bathmetry at the location comparable to historical conditions once the dredged material has been placed.

Concerns were previously raised that construction of pile dikes would create perches that aid bird predation of juvenile salmonids, particularly by double-crested cormorants. To address this concern, the Corps has placed bird excluders atop numerous Columbia River estuary pile dikes. These excluders, which are placed atop pilings and spreaders on pile dike structures, were intended to preclude perching by double-crested cormorants. Oregon State University researchers have monitored these devices, and their efficacy in precluding cormorants, in 2000 and 2001. Their observations indicate that the bird excluders effectively preclude cormorants from perching on pile dikes and also significantly reduce the number of cormorants foraging in the water column in the vicinity of the pile dikes.

The following actions will be taken as part of the Miller-Pillar ecosystem restoration feature:

- Fund and implement construction effort
- Monitor post-construction benthic productivity and fish species composition and density on the restoration site and an adjacent control site
- Operate and maintain pile dikes and associated bird excluders for project life

8.2.4 Tenasillahe Island Interim and Long-Term Restoration

Two actions are anticipated for this location. The interim action would be directed at improving connectivity and water exchange between sloughs/backwater channels interior to the levees and the Columbia River. This would be accomplished through interim and long-term improvements to tidegates and provision of controlled inlets to improve water movement and accessibility for juvenile salmonids. Implementation of the interim action is contingent on hydraulic engineering analyses to ensure that any improvement will not compromise habitat integrity for Columbia white-tailed deer that inhabit Tenasillahe Island**.** Under the long-term action, the levees would be breached to restore full tidal circulation to approximately 1,778 acres of former intertidal marsh/mudflat and forested swamp habitat. This long-term action is contingent on delisting of the Columbia white-tailed deer and determination that such actions are compatible with the purposes and goals of the refuge, to include restoration of intertidal marsh/mudflat and forested swamp habitat for ESA Critical Habitat for salmonids.

Tenasillahe Island is a large natural island in the Columbia River between RM 35 and 38 and immediately downstream of Puget Island. Actions to place levees around the bulk of the island began around 1910. Currently, approximately 1,778 acres of Tenasillahe Island are protected from inundation by the Columbia River. A main flood protection levee encompasses the majority of the island except for a parcel at the upstream tip. Tidegates, located at the downstream tip of the island, drain interior waters to Clifton Channel.

Prior to construction of these levees, the island was primarily intertidal in nature, with three major and numerous minor natural drainage channels bisecting the island. Intertidal marsh and mudflats, subtidal channels, and forested swamp historically would have been the principal fish and wildlife habitat on the island. Juvenile salmonids use of the historical habitat at Tenasillahe Island was probably extensive given the large extent of subtidal channels. The intertidal marsh and mudflat habitat would have supported substantial populations of various waterfowl and shorebirds, plus many other species, and would have exported considerable detritus to the Columbia River estuary.

Tenasillahe Island is currently a component of the Julia Butler Hansen Columbia White-Tailed Deer National Wildlife Refuge. The island is managed to provide habitat for the deer, a federally listed endangered species. The levees, tidegates, and other associated infrastructure are maintained to aid in the management of the Columbia white-tailed deer. Interior lands are primarily maintained as wet pastures through mowing and grazing activities to provide adequate quantity and quality of forage for the deer.

The Service's recovery population goal for Columbia white-tailed deer is a minimum of 400 deer occurring in three secure and viable subpopulations (e.g., 50 deer with 32 breeding adults). There are currently four recognized subpopulations of Columbia white-tailed deer located at Tenasillahe Island, Westport, the mainland portion of the Julia Butler Hansen Columbia White-Tailed Deer National Wildlife Refuge, and Puget Island. However, only the mainland Julia Butler Hansen Columbia White-Tailed Deer National Wildlife Refuge and Tenasillahe Island subpopulations are considered secure subpopulations as both are refuge lands owned by the USFWS. Consequently, one additional secure and viable population is required to meet the recovery plan goal.

8.2.4.1 Step 1 – Interim Restoration Features

The interim ecosystem restoration features include retrofitting tidegates and introduction of Columbia River flows to the heads of two sloughs in order to reintroduce juvenile salmonids to the interior sloughs and assure their ability to exit the interior sloughs. Tidegates would be retrofitted with aluminum doors or other suitable structures to allow fish access and egress over longer periods of time and tidal flows. Controlled inlet structures could be placed at the heads of sloughs to allow for ingress of Columbia River waters, thus drawing juvenile salmonids into the slough system. Approximately 92 acres of backwater channel habitat would be affected by the proposed interim ecosystem restoration feature to improve tidegates for fish access/egress and to install water control structures to improve flow and circulation.

The north slough that separates the main portion of Tenasillahe Island from the island abutting Multnomah Channel and the Columbia River upstream of Multnomah Channel could be improved by placement of a controlled inlet structure at the Columbia River and improvements to the tidegates at Multnomah Channel (Station 228+01). The headwaters of the main western slough channel, in the interior of Tenasillahe Island, are adjacent to Clifton Channel. Historically, there was a pump house and tidebox at this location (Station 4+44). The tidebox is no longer functional. A controlled inlet could be constructed at this location for importation of Columbia River flows and thus juvenile salmonids. Similar to the north slough, improvements to the tidegates would be required at Station 270+93 to ensure flows are exhausted and juvenile salmonids can readily exit the system.

The following actions will be taken as part of the Tenasillahe Island interim restoration effort:

- Conduct hydraulic engineering analyses of inlet and tidegate structures to ensure water control structures are of sufficient design and capacity to safeguard Columbia white-tailed deer habitat interior to the main flood control levees

- Fund and implement construction efforts for the interim

- Monitor post-construction benthic productivity and fish species composition and density on the restoration site and an adjacent control site

- Prepare annual reports of post-construction results to the Adaptive Management Team

8.2.4.2 Step 2 – Long-Term Restoration Features

The long-term ecosystem restoration features include restoring Tenasillahe Island to its historical habitat mixture. This long-term feature would be contingent on securing two (for a total of three) secure and viable Columbia white-tailed deer habitat sites. Options include securing lands in the subpopulation areas previously identified and possible acquisition of lands and habitat development at Lord-Walker, Fisher-Hump, and/or Cottonwood-Howard Islands. Cottonwood-Howard is discussed specifically below. These deer habitat acquisition actions are proceeding at various paces. The time frame for when two additional secure and viable subpopulations will be attained is unknown.

The attainment of three secure and viable subpopulations of Columbia white-tailed deer, not to include Tenasillahe Island, would provide an excellent opportunity to restore 1,778 acres of ESA Critical Habitat for salmonids in the Columbia River estuary. The restoration action would require removal of the downstream plugs on the interior drainage channels and reconnection via open channels of historical upstream connections. Construction actions could be easily implemented in a short timeframe at a minimal cost.

The following actions will be taken as part of the Tenasillahe Island long-term restoration effort:

- When Columbia White Tailed Deer are delisted, develop a plan to remove downstream plugs on the interior drainage channels and reconnect via open channels

- Monitor post-construction benthic productivity and fish species composition and density on the restoration site and an adjacent control site

- Submit annual reports of post-construction results to the Adaptive Management Team

8.2.5 Cottonwood/Howard Islands Columbia White-Tailed Deer Introduction

This feature is intended to provide secure habitat for Columbia white-tailed deer and represents an essential step toward the long-term restoration of historical habitats at Tenasillahe Island. The restoration feature, located at RM 68 to 71.5, is contingent on acquisition of Cottonwood and Howard Islands in their entirety by the Sponsor Ports, primarily for dredged material disposal actions associated with the Project. There is substantial acreage at Cottonwood/Howard Islands outside the disposal site boundaries for development or preservation as Columbia white-tailed deer habitat. Riparian forest currently exists in a relatively large block on the Carroll's Channel side of the island. Buffer zones (300 feet wide, per agreement with NMFS) have been established around the selected disposal sites to allow for natural development of riparian forest. Given the large size of these islands, which are presently joined as one island, and the presence of large blocks of riparian forest, the introduction of Columbia white-tailed deer by the USFWS is seen as viable at this location. Post-introduction monitoring will be required to determine the success of the introduction and whether a secure, viable population of Columbia white-tailed deer has been established.

Those areas designated for dredged material disposal and access/egress of dredging-related equipment in the EIS for the Project will be retained for that category of use for the life of the Project. Only lands exterior to the designated disposal site will be considered for restoration purposes.

The following actions will be taken as part of the Cottonwood/Howard Island ecosystem restoration feature:

- Land acquisition
- All actions necessary to accomplish translocation of Columbia white-tailed deer to Cottonwood/Howard Island, including NEPA/ESA coordination
- Funding of translocation efforts
- Habitat O&M
- Monitoring efforts to assess Columbia white-tailed deer translocation, including preparing an annual report for the Adaptive Management Team on the status of the translocation effort

8.2.6 Bachelor Slough Restoration

The Bachelor Slough Restoration action is located within the boundaries of the Ridgefield National Wildlife Refuge near Ridgefield, Washington. Bachelor Slough is a 2.75-mile-long side channel of the Columbia River branching off the mainstem at RM 91.5. The slough empties into Lake River, which opens into the Columbia River at RM 87.5. Bachelor Slough delineates the east boundary of Bachelor Island. The proposed instream restoration action would encompass 100 acres along the length of the slough. Approximately 132,000 cubic yards of material would be dredged from the bottom of the slough.

Bachelor Slough submerged lands and the upland disposal site adjacent to the Columbia River are both the property of WDNR and USFWS. Discussions are under way to secure easements from WDNR for use of their property for disposal.

The slough provides salmonid rearing habitat and, possibly, minor adult migration habitat. The slough currently is heavily silted, which impedes seasonal water flow, elevates water temperatures, reduces vegetation growth, and inhibits fish passage. The silted condition subjects native fishes and aquatic wildlife to seasonal high levels of disturbance, extreme temperatures, unsuitable food and cover resources, and entrapment conditions. Removing some of the siltation while retaining some of the natural barriers to boat traffic will enhance fish habitat. This restoration feature includes removing invasive tree species and reed canarygrass and replacing them with native willows, ash, and cottonwoods on 6 acres.

This restoration feature proposes the removal of silt from approximately 300 feet north of the slough mouth (south tip of Bachelor Island) to the north end of the slough where it merges with Lake River. The first 300 feet of the slough mouth will not be dredged completely so as to discourage public recreational boating. Recreational boating, including jet skis, is a recognized source of wildlife disturbance and erosion within the slough. Current conditions (i.e., shallow water and minimal access at the mouth) limit boating activities to relatively small watercraft and seasonal use.

All dredging activity would occur in-water from November 1 to February 28 to minimize potential impacts to fish. The slough will be dredged to a depth of approximately 0.0 mean sea level at the bottom, with slopes of 7:1 to the adjacent embankments. The Ridgefield National Wildlife Refuge has three pump stations along Bachelor Slough. Deeper excavations will occur around the three refuge intake pumps to improve pump efficiency. Each pump intake is screened to prevent entrainment of juvenile salmonids; therefore, the proposed feature will have no adverse effect on salmonids. An estimated 132,000 cubic yards of dredged material will be removed.

Restoration of the embankment vegetation will occur on approximately 6 acres of the Bachelor Island shoreline. This will include the removal of invasive plants such as reed canarygrass, false indigo bush, and Himalayan blackberry. These plants will be replaced with a more palatable grass mixture, willows, and cottonwoods.

A specific disposal location for material dredged from the slough is being evaluated. If the material has a suitable silt content, it could be placed on old dredged material disposal locations, either upland or along the Columbia River shoreline. There the material would provide a suitable substrate for development of riparian forest habitat. Natural establishment of riparian forest trees would be relied on for stand development because the presence of bare mineral soil in May through early June during seed dispersal by cottonwoods and willows will result in natural establishment of riparian forest stands. Dredged material will provide that type of substrate; minor tillage in spring prior to seed dispersal would be sufficient to control weeds or other competitive vegetation that may develop between disposal and spring.

The Bachelor Slough ecosystem restoration feature is contingent on the Corps' evaluation of sediment chemistry and approval by WDNR to dispose of dredged material on their property for further riparian habitat creation. Backwater channels are more likely to contain fine-grained sediments (silts) with a high organic content and, therefore, a greater likelihood of contaminants (e.g., PCBs, DDT, DDE) than coarser-grained sands with low organic content found in the main navigation channel. As a result, a sediment chemistry evaluation is necessary to determine contaminant levels. Construction is proposed using a pipeline dredge, working during November 1 through February 28, and disposing of dredged material on WDNR property to increase the riparian habitat.

The following actions will be taken as part of the Bachelor Slough ecosystem restoration feature:

- Conduct sediment chemistry evaluation
- Conduct dredging of Bachelor Slough
- Obtain real estate instruments in order to dredge Bachelor Slough and place materials at an upland location

- Provide initial tillage of upland dredged material disposal site, if necessary, to provide suitable substrate for riparian tree seedling establishment
- Restore 6 acres of riparian forest habitat
- Perform riparian forest O&M
- Perform O&M dredging, as required, to maintain restoration depths in Bachelor Slough
- Monitor fisheries use of Bachelor Slough for a 5-year period, including providing annual and final reports on findings to the Corps, NMFS, and Washington Department of Fish and Wildlife (WDFW)

8.3 Ecosystem Research Actions

Ecosystem research actions are measures taken by the Corps as part of the proposed Project to assist the efforts of the Corps, the Services, and others in the broader issues of understanding the lower Columbia River ecosystem. These research actions address indicators of the salmonid conceptual model where additional studies would provide useful information to the recovery of the species. These research actions will advance the knowledge base for the recovery of the species. The annual and cumulative results will be presented to the Adaptive Management Team (see Section 9).

Research actions proposed for the Project are shown in Table 8-1. This table identifies the ecosystem research actions that the Corps proposes to implement under this BA.

Table 8-1: ESA Sec. 7(a)(1) Ecosystem Research Actions (ERA)

ERA Number	Indicator	Monitoring Task	Justification	Duration	Data Analysis	Management Decision
ERA-1	Tidal Marsh and Swamp Habitat, Shallow Water and Flats Habitat, Water Column Habitat	Add one or two additional transects in different habitat types similar to those being done for the NMFS studies currently under way with AFEP	Provide additional habitat and salmonid distribution information for the estuary. Useful in establishing inventory information for future monitoring or restoration.	Begin before construction and for 3 years after completion of the project.	Record value and use of different habitat types for juvenile salmonids and cutthroat trout.	Determine if task should continue and what funding source is appropriate.
ERA-2	Tidal Marsh and Swamp Habitat, Shallow Water and Flats Habitat, Water Column Habitat	Add upriver transect (upstream of RM 35) to evaluate cutthroat and juvenile salmonid use of the riverine area.	Little is known about the species use of this habitat. To provide additional information regarding salmonids use of this habitat.	Begin during construction and end 3 years after completion of the project.	Record value and use of different habitat types by juvenile salmonids and cutthroat trout.	Determine if task should continue and what funding source is appropriate.
ERA-3	Bathymetry, Shallow Water and Flats Habitat	Conduct bank-to-bank hydrographic surveys of the estuary.	Has not been done in 20 years and is needed to assess available habitat and restoration actions.	Once, prior to construction.	Bathymetry will be available for shallow water areas in the estuary.	None required.
ERA-4	Contaminants	In conjunction with ongoing studies of juvenile salmonids habitat utilization in the lower Columbia River collect and analyze juvenile salmonids and their prey for concentrations of chemical contaminants.	Provide additional data on contaminants in listed salmonids and their prey. Useful in establishing inventory information for future monitoring or restoration.	Begin before construction during and up to 3 years after construction, depending on the results.	Record concentrations of persistent contaminants (e.g., DDTs, PCBs, PAHs, dioxin-like compounds) in juvenile salmonids and prey.	Determine if task should continue and what funding source is appropriate.
ERA-5	Contaminants	In conjunction with above contaminant study, assess sublethal effects of contaminants (e.g., growth, disease resistant) on salmonids.	Provide additional data for established contaminants thresholds effect levels to ensure that guidelines are protective of salmonids; to better characterize performance of juvenile salmonids in the estuary.	Begin before construction during and up to 3 years after construction, depending on the results.	Record health status of juvenile salmonids collected above.	Determine if task should continue and what funding source is appropriate.
ERA-6	Salinity, turbidity, and phytoplankton	ETM Workshop	To further the knowledge of the ETM and the listed stocks.	Once	Not required	None required.

Any study done should fit into the overall research effort that is being conducted or proposed by LCREP, NMFS, BPA and the Corps. In this way it will not be a duplication of effort will provide results that fit into what should be an overall goal for research in the estuary.

8.4 Analysis of Effects of Ecosystem Restoration Features and Research Actions

This section analyzes the potential to ESA-listed fish, wildlife, plants, and insects arising from implementation of six ecosystem restoration features and associated research actions set forth in Section 8.0. Additionally, this section addresses potential effects on salmonids associated with the three ecosystem restoration actions described in Section 3 of this BA and Chapter 4 of the FEIS (Corps, 1999a). Impacts to terrestrial species under USFWS's jurisdiction for these three actions and Miller/Pillar Island were previously addressed in the BA for the Project. Impacts to marine mammals and sea turtles were addressed in the DMMP BA. The conclusion of "no effect" from that document applies to the restoration features and research actions discussed here and is incorporated here by reference.

Ten species (Columbia white-tailed deer, bald eagle, marbled murrelet, western snowy plover, brown pelican, Oregon silverspot butterfly, Howellia, golden paintbrush, Bradshaw's lomatium, and Nelson's checkermallow) occur in the general area of these restoration actions. For detailed information on these species relative to their presence along the Columbia River, the reader should reference the BAs and BOs previously published for the Columbia River DMMP and Columbia River Channel Improvements. Two species, the peregrine falcon and the Aleutian Canada goose, have been delisted since the consultation on the FEIS was concluded and are not addressed in this BA. A brief description of the Corps' determinations is presented below.

Seven of the 10 species listed above (marbled murrelet, western snowy plover, Oregon silverspot butterfly, Howellia, golden paintbrush, Bradshaw's lomatium, and Nelson's checkermallow) do not occur in the areas identified for the nine ecosystem restoration features and research actions or were addressed in the previous BA (Corps, 1999b). Therefore, it is our determination that there will be "no effect" to these species from the six proposed ecosystem restoration actions set forth in this section. Determinations in the original BA for listed species (Corps, 1999b) for the three ecosystem restoration actions identified in the FEIS (Corps, 1999a) remain valid.

8.4.1 Ecosystem Restoration Features

8.4.1.1 Federally Listed Salmonid ESUs

Presence, abundance, distribution, and habitat association and use information pertaining to listed stocks are included in previous sections. The reader should refer to those sections for general information.

Benefits associated with individual restoration features are more clearly defined in the discussion for each action. Typically, the benefits associated with the proposed actions entail preservation of existing tidal marsh and swamp habitat, restoration of tidal marsh and swamp and shallow water and flats habitat and associated benthic invertebrate and fish populations, development of riparian forest, and improvements in access to side channel/backwater habitats.

Five of six restoration features identified in Section 8.2 (Lois Island Embayment Habitat Restoration, Purple Loosestrife Control, Miller/Pillar Habitat Restoration, Tenasillahe Island Interim and Long-term Restoration, and Bachelor Slough Restoration) occur in water and have the potential to affect listed salmonids. The translocation of Columbia white-tailed deer to Cottonwood/Howard Island will have no effect on listed salmonids as the action is upland in nature and does not affect habitat used by these species.

Two of three restoration actions identified in the FEIS (Corps, 1999a) (Restore Shallow Water Habitat, Tidegate Retrofits for Salmonid Passage and Improved Embayment Circulation) occur in-water, so they have the potential to affect listed salmonids. The Shillapoo Lake Restoration action, in the current configuration, would have no effect on listed salmonids because the action is interior to main flood control levees and upland in nature and, therefore, does not impact habitat used by these species.

Lois Island Embayment Habitat Restoration

Chinook salmon, primarily fall chinook subyearlings, were the most abundant (94 percent) juvenile salmonid captured in the embayment by Cates (1983). Chum and coho salmon and coastal cutthroat trout represented the remaining juvenile salmonids captured in the Lois Island Embayment by Cates (1983). The lowered presence of juvenile salmonids other than fall chinook subyearlings may be attributable to the present condition of the embayment, which is a large body of open water (389 acres), approximately 18 feet deep on average, with a rather uniform bottom substrate and lacking in structural diversity. Historically, the area included complex tidal marsh and swamp habitat with a deeper subtidal channel bisecting the area.

The objective of this restoration action is to mimic the historical substrate conditions in terms of elevation and rely on natural repopulation of the intertidal marsh, mudflat, and subtidal habitats by native flora and fauna. Adjacent tidal marshes and swamps, and shallow water and flats habitats are expected to provide the source populations for flora and fauna re-establishment.

The proposed restoration feature would be beneficial to listed salmonids because primary (plant) and benthic productivity should approach historical levels over time. The return of 389 acres of tidal marsh and swamp and shallow water and flats habitats represents a substantial restoration of estuarine productivity.

Construction actions for the restoration feature may result in temporary impacts to listed salmonids. The site will be restored using a pipeline dredge to transfer material placed by hopper dredges at the upstream end of the Tongue Point turning basin. Fish are expected to avoid the immediate area of the discharge during disposal operations. The materials to be placed are clean, median-grained sands from the Columbia River navigation channel; consequently, turbidity plumes associated with the discharge are expected to be minimal because most material would readily settle to the bottom. Much of the embayment restoration can occur during navigation channel construction when the bulk of the materials would be generated. However, a number of years of maintenance dredging would also be required to complete the restoration. Materials to be placed in the embayment are primarily clean, medium-grained sands that meet the criteria for in-water disposal. No contaminant concerns are foreseen (see Section 6.1.5, Accretion/Erosion). Timing windows and BMPs identified in Section 6 will apply to actions in this area. Materials stored temporarily in the Tongue Point turning basin are not expected to raise the river bottom to more than 30 feet below the surface; therefore, no effects to salmonid habitat are expected.

Recolonization of the restored embayment by plants and benthic invertebrates will take 5 to 10 years or more, depending on the species and their means of colonization. The tidal marsh fringing the embayment and the large expanses of tidal marsh in Cathlamet Bay represent a large source of plant propagules for the restoration site. Similarly, benthic organisms are abundant in Cathlamet Bay and represent an excellent source population for recolonization of the embayment. Benthic productivity and related use by salmonids may be less for an undetermined interim period as populations reestablish and densities increase. Plant productivity should increase steadily from current levels because the restoration actions would not affect the fringing tidal marsh habitat and swamp habitat currently present at the embayment.

It is our determination that the proposed action may adversely affect listed salmonids during restoration of historical elevations; however, over the long term, the proposed action should beneficially affect listed salmonids.

Purple Loosestrife Control

The restoration feature for purple loosestrife control would include an integrated pest management approach using biological agents, herbicides, and mechanical control measures. These actions would typically occur in the upper elevations of tidal marsh habitat and have little likelihood of adversely affecting salmonids directly or indirectly. Rodeo, an EPA-registered chemical approved for over-water application, would be used in conjunction with the other control measures. Rodeo application will result in the short-term loss of some native vegetation. It is anticipated that the herbicide will be wicked on to purple loosestrife, thereby lessening the potential for impacts to native vegetation, which is typically shorter in stature. Mechanical control (pulling) would only affect a small area at any given time, typically during lower tidal stages.

The purpose of this restoration feature is to eradicate purple loosestrife in the Columbia River estuary and retain the diverse, native flora composition of the tidal marsh habitat. Purple loosestrife domination of the tidal marsh flora would negatively impact benthic invertebrates that depend on detrital export from the tidal marsh habitat. Purple loosestrife domination would be detrimental to juvenile salmonids.

Our determination is that the use of herbicides as part of this restoration feature will have some short-term adverse effects but, in the long-term, the proposed restoration feature is likely to beneficially affect listed salmonids.

Miller/Pillar Habitat Restoration

The proposed restoration feature centers on restoration to its historical depth of an erosive area of the Columbia River at approximately RM 26. A NMFS study has indicated that the historical depth is a more productive elevation for benthic invertebrates, and therefore for juvenile salmonids as well. Site restoration would hinge on placement of dredged material to attain historical elevations and the construction of a pile dike field to hold the material in place once it is deposited on location.

Construction of this restoration action may result in the temporary displacement of juvenile salmonids from the immediate area of the discharge pipe or the pile dike construction location. Once construction is completed, future potential disturbance actions would be limited to O&M of the pile dikes, an intermittent effort over many years. Pilings and spreaders would be fitted with bird excluders to minimize or eliminate use by double-crested cormorants. This feature would also require intermittent O&M activities, but is water surface-oriented and poses minimal potential for impact to listed ESUs.

A previous study has established that driving of wood piles with an impact hammer does not produce sounds that are in the hearing range of salmonids. The action is not considered to affect salmonids.

It is our determination that the construction and O&M elements of this restoration action, for the short term, are likely to adversely affect listed salmonids, but are not likely to adversely affect them in the long term.

Tenasillahe Island

Two actions are anticipated as part of this ecosystem restoration feature. The interim action would be directed at improving connectivity and water exchange between sloughs/backwater channels interior to the levees and the Columbia River. This would be accomplished through improvements to tidegates and provision of controlled inlets to improve water movement and accessibility for juvenile salmonids. These backwater channels represent rearing habitat for juvenile salmonids that is assumed to receive minimal use at present.

Over the long term, the levees would be breached to restore full tidal circulation to approximately 1,778 acres of former tidal marsh and swamp and forested swamp habitats. This long-term action is contingent on the delisting of Columbia white-tailed deer and determination that such actions are compatible with the purposes and goals of the refuge, to include restoration of tidal marsh and swamp and forested swamp habitats for ESA Critical Habitat (salmonids).

As a result of this ecosystem restoration feature, from the interim action to improve connectivity of interior channels to full restoration of tidal circulation to 1,778 acres of estuarine habitat, a substantial gain in salmonid habitat is envisioned. Increased export of detritus to the estuary from re-established marshes or forested swamp is also foreseen. Both the interim action and full-scale restoration would result in juvenile salmonids gaining additional acres of productive habitat for rearing and foraging.

Construction impacts related to either the interim or full-scale restoration feature are anticipated to be of short duration (a few days to a couple of weeks). The primary impact is likely to be an increase in turbidity localized around the construction actions. Through appropriate timing, impacts to juvenile salmonids in the immediate construction area can be further minimized.

It is the Corps' determination that the proposed action may have some short-term adverse effects, but is expected to result in long-term beneficial effects for listed salmonids.

Tidegate Retrofits for Salmonid Passage

This proposed ecosystem restoration feature is described in Section 3 and in more detail in Chapter 4 of the FEIS (Corps, 1999a). The feature consists of improvements to existing tidegates to improve anadromous fish movement through the structures. The Corps solicited lists of potential restoration actions from the Oregon and Washington Departments of Fish and Wildlife. Three Oregon tributaries to the Columbia River – Tide Creek, Grizzly Slough, and Fertile Valley Creek – were identified for ecosystem restoration actions. Two Washington streams – Burris Creek and Deep River—were also identified for retrofitting of tidegates. Additional tributaries would be considered if identified.

The new tidegates will be either a hinged door that fits over the end of a large-diameter drainage pipe that opens and closes in response to changes in hydraulic pressure or small sliding doors. New drainage pipes may be required at some locations depending on the age and condition of the current drainage pipe. The purpose of the retrofit is to increase the amount of time that fish have access through these structures. Construction would typically take place in late summer to take advantage of lower water levels, dry soil conditions, and the general absence of fish. It is the Corps' determination that the potential for impacts to listed ESUs is minimized. Construction actions are also of short duration (e.g., less than one week per structure) and soil disturbance, thus turbidity, would be typically minimal.

It is the Corps' determination that the construction element of this restoration action, for the short term, may affect but is not likely to adversely affect, listed salmonid ESUs, including coastal cutthroat trout. Longterm, the proposed restoration may affect (beneficial) the suite of listed fish species.

The tidegate retrofit restoration feature is estimated to provide or improve anadromous fisheries access to 38 miles of tributary streams. These tributaries contain spawning, stream rearing, and (near their confluence with either the Columbia River or a more major tributary) backwater channel and freshwater marsh habit for rearing and/or overwinter refuge from floods.

Access through tidegates would be improved through installation of sliding doors and/or tidegates. The sliding doors (fish slides) can be left open during outmigration and inmigration periods to allow anadromous fish the opportunity to access or egress the stream on their timeframe, rather than strictly when tidal conditions (outgoing) provide for the tidegates to open.

Walker/Lord and Hump/Fisher Island Improved Embayment Circulation

This proposed ecosystem restoration feature is described in more detail in Chapter 4 of the FEIS (Corps, 1999a). The connecting channels between the Columbia River and the embayment formed by the connection of islands through dredged material disposal will be excavated. These embayments are generally open at only one end. As a result, water circulation is impeded and sediment settling tends to create a shallow, warm water environment. The purpose of this restoration action is to improve water flow and circulation, thereby lowering embayment temperatures and creating a network of channels. This feature should increase salmonid presence and foraging conditions for juvenile salmonids.

Construction activities are primarily upland in nature and involve construction of a channel in a historical dredged material deposition area. A brief period of in-water construction would occur when the channels at the embayment and river are opened. Given the short duration of the construction action and the fact that material to be excavated is primarily medium-grained sand, turbidity in adjacent waters should be of short duration and extent.

Construction timing would typically be late summer to take advantage of lower water levels, dry soil conditions, and the general absence of fish. As a result, the potential for impacts to salmonids is minimized.

It is our determination that the construction element of this restoration action may have short-term effects, but is not likely to adversely affect listed salmonids. Longterm, the proposed restoration should beneficially affect listed salmonids.

Martin Island Embayment

The proposed mitigation action entails placement of dredged material, with a cap of topsoil, to develop approximately 32 acres of tidal marsh habitat. A more detailed description of the proposed mitigation action can be referenced in Appendix G of the FEIS (Corps, 1999a). The existing embayment was dredged to provide fill for Interstate 5. The mitigation objective is to create intertidal marsh habitat for fish and wildlife, which would increase detrital export to the Columbia River.

Although the proposed mitigation action would have some effect on an aquatic environment that receives transitory use by juvenile salmonids, the intertidal habitat would be expected to increase the export of detrital material from the marsh habitat and provide for increased energy input to the Columbia River and the estuary. This would benefit benthic invertebrates, including those species that are used as forage resources by juvenile salmonids. In addition, development of tidal marsh habitat would not preclude use of the embayment by juvenile salmonids except during low tide periods.

Construction placement of dredged material and topsoil will increase turbidity. However, the principal material to be placed is medium-grained sand from the navigation channel. Sand would be expected to settle quickly, resulting in little escape of turbidity to the adjacent side channel. Placing topsoil would create more turbidity than placing sand. The embayment is a quiet water environment with a narrow access channel. Consequently, export of turbidity to the side channel would be further lessened.

The proposed action may affect, but is not likely to adversely affect, listed stocks of salmonids.

Bachelor Slough

Restoration actions at this location are geared toward deepening the existing side channel habitat to remove accumulated sediments. From a fisheries perspective, this would increase flows traveling through the slough and should decrease water temperatures. Juvenile salmonids would be more likely to be drawn into Bachelor Slough under these changed conditions during the outmigration. Cooler temperatures would be beneficial to fish drawn into Bachelor Slough.

Disposal of material dredged from Bachelor Slough provides an opportunity to develop riparian forest on an old, sand-covered disposal site immediately adjacent to the Columbia River and within the zone of ESA Critical Habitat. Riparian forest restoration would provide for detrital (leaf) and insect faunal export to the Columbia River. Long term, riparian forest habitat would provide for export of large woody debris to the Columbia River and its estuary.

Sediment quality would be evaluated prior to implementation of the restoration feature to ensure contaminants are not an issue. The feature would be discontinued if contaminants were determined to be outside established regulatory parameters for upland disposal. Timing restrictions for pipeline dredging will minimize impacts to salmonids from dredging or disposal operations, particularly during in-water disposal.

The construction element of this restoration action may affect, but is not likely to adversely affect, listed salmonids. Long term, the proposed restoration may beneficially affect listed salmonids.

Shillapoo Lake Ecosystem Restoration

A detailed description of this ecosystem restoration feature is presented in Section 3 of this BA and Chapter 4 of the FEIS (Corps, 1999a). The principal construction effort for this feature will occur interior to the main flood control dikes. Additional work will occur around the tidegate and pump station that exhausts interior waters to Lake River. A porous rock levee would be constructed in the discharge channel to prevent fisheries entry into the Shillapoo Lake system where entrapment could otherwise occur. Construction of the rock levee would probably occur in late summer-early fall to take advantage of seasonally low water levels and the minimal presence of juvenile salmonids. A pump station to supply auxiliary water to the restoration area will either be added and/or an existing WDFW pump station will be upgraded. Thus, little of the proposed construction work will occur outside the flood protection levees. Pump installation and construction of the rock levee would result in negligible turbidity increase in the immediate area of the activity. Screens will be placed to prevent entrainment of juvenile salmonids by pumps.

It is the Corps' determination that the proposed action may affect, but is not likely to adversely affect, listed stocks of salmonids.

8.4.1.2 Columbia White-Tailed Deer

Restoration features for Lois Island Embayment, Purple Loosestrife Control, and Bachelor Slough will have no effect on Columbia white-tailed deer because this species is not present at these in-water habitat restoration locations.

Cottonwood/Howard Island Columbia White-Tailed Deer Introduction

No Columbia white-tailed deer are currently located on Cottonwood-Howard Island. USFWS proposes to transplant Columbia white-tailed deer to the island contingent on acquisition of the island by the Corps and the Sponsor Ports. USFWS will determine effects on Columbia white-tailed deer in future NEPA/ESA documentation of their Columbia white-tailed deer translocation efforts. There is some potential for take as a result of this translocation. Because the USFWS will be responsible for translocation, they will serve as the action agency for this effort and will reinitiate consultation at the time of the translocation effort when the agency has developed specific relocation plans.

Tenasillahe Island Interim and Long-Term Restoration

The restoration features proposed at Tenasillahe Island may result in temporary disturbance to Columbia white-tailed deer in the immediate area of the inlet and outlet structures that are being modified during the construction period. These disturbance bouts may entail a few days each at each structure and are severely constrained spatially. Design of inlet and outlet (water control) structures will be based on hydraulic engineering analyses, to ensure that water imported into the sloughs interior to the flood protection levees can be exhausted quickly and efficiently without flooding adjacent Columbia white-tailed deer habitat. The inlet structures will be designed with closure gates to ensure that inflows can be shut off during flood or high precipitation events to prevent interior flooding of Columbia white-tailed deer habitat. Therefore, it is our determination that the proposed restoration feature at Tenasillahe Island may affect, but is not likely to adversely affect, Columbia white-tailed deer.

The long-term restoration feature will involve the relocation of a substantial portion of the Tenasillahe Island Columbia white-tailed deer population. It should be noted that no relocation will occur unless the Columbia white-tailed deer is delisted; therefore, no adverse effect is expected for this species.

8.4.1.3 Bald Eagle

The Columbia River Recovery Zone (RZ 10), Pacific Bald Eagle Recovery Plan, which includes the proposed ecosystem restoration actions, has substantially exceeded the target number of bald eagle territories for both Habitat Management Goals (HMGs) and Recovery Population Goals (RPGs). For RZ 10, the HMG is 47 breeding territories and the RPG is 31 breeding territories. Eighty-nine breeding territories were surveyed in 2001 and 86 of these surveyed territories were occupied. Nesting outcome was determined for 85 nesting territories, of which 52 (61 percent) were successful in producing young. The 79 young represented a production rate of 0.93 young per occupied territory, slightly higher than the 5-year average of 0.85 young per occupied territory. For 2001, 1.52 young were produced per successful territory.

The Pacific State Bald Eagle Recovery Plan also identifies other criteria that must be attained in order for delisting to occur in addition to the HMGs and RPGs. These include an annual production rate of 1.0 young per occupied territory and an average success rate of not less than 65 percent over a 5-year period. Bald eagles in RZ 10 exceed two of the three criteria and are near the goal for young per occupied territory set forth in the Recovery Plan. Thus, there is room to accept some impact to this population arising from implementation of ecosystem restoration measures, particularly given that the long-term benefits associated with the identified measures should be beneficial to bald eagles. The potential for impacts will be minimized as the Corps funds the Oregon Cooperative Fish and Wildlife Research Unit to fly bald eagle territory occupancy and productivity flights annually and uses the results to assess proposed actions and minimize or avoid disturbing bald eagles.

Lois Island Embayment

The proposed restoration of intertidal marsh/mudflat habitat and shallow subtidal channels in the Lois Island Embayment has the potential to initially adversely affect two resident pairs of bald eagles (e.g., the John Day Point/Lois Island and Tongue Point/Mill Creek pairs). These pairs nest adjacent to the proposed restoration area. The John Day Point/Lois Island pair's nest is approximately 1,500 feet from the nearest edge of the restoration area. The Tongue Point/Mill Creek pair's nests (includes alternatives) are much farther distant. Disturbance to the John Day Point/Lois Island nesting birds (at the nest location) can be avoided by directing construction actions to distant locations from their nest locations. The Tongue Point/Mill Creek pair's nest locations are sufficiently distant from the work area to preclude disturbance to their nesting activities.

There is potential for impacts to foraging activities of these pairs from restoration of the Lois Island Embayment. Such disturbance is more likely for the John Day Point/Lois Island pair than the Tongue Point/Mill Creek pair. The latter pair would be expected to focus their foraging activities near the Tongue Point docks, Tongue Point proper, and northward to Taylor Sands. These areas are sufficiently distant from the construction area as to preclude most incidences of disturbance. Further, this pair is habituated to substantial human activity associated with Tongue Point docks, Job Corps Station, and the Coast Guard Station plus sport fishing off Tongue Point. The John Day Point/Lois Island pair established their territory on the line that previously delineated the boundary between the Twilight and Tongue Point/Mill Creek pairs. Their obvious foraging area would be along the shorelines of Lois Island, including that abutting the embayment. As the restoration action encompasses an area of 389 acres and specific actions are restricted to a small portion of the total area at any given time, this pair will have ample opportunity to forage within their territory.

The consequence of implementation of ecosystem restoration actions at Lois Island Embayment may be temporary impacts to foraging activities of the John Day Point/Lois Island pair. Ultimately, the development of intertidal mudflat/marsh habitat interspersed with shallow subtidal channels will increase prey numbers and diversity for both pairs.

Thus, our final determination for this proposed restoration action is likely to have adverse effects initially, but has a long-term beneficial effect.

Purple Loosestrife Control

Purple loosestrife control measures will occur at intertidal marsh habitats scattered throughout the Columbia River estuary. Similarly, a resident, nesting bald eagle population is also scattered throughout the Columbia River estuary. Purple loosestrife control measures are expected to occur from June to September, inclusive. Thus, there will be overlap with the bald eagle habitat during the nesting period and human-eagle encounters can be expected to occur periodically during the execution of control measures. The potential exists for occasional disturbance to foraging bald eagles from implementation of survey and control actions. Such disturbances are expected to be short term in nature and only entail a small portion of the territorial area of any given bald eagle pair. Thus, alternative foraging areas would remain available to resident bald eagles within their territories. A 1,500-foot area around an active nest would be avoided until young are successfully fledged and/or the nest is determined to be inactive for the breeding season.

The control of purple loosestrife in the intertidal marshes of the Columbia River estuary is an integral element of maintaining the productivity of these marshes for juvenile salmonids, waterfowl, bald eagles and other species. Loss of this productivity due to dominance by an exotic plant will ultimately harm all fish and wildlife populations that utilize these intertidal marshes. Consequently, short-term, controlled impacts to bald eagles are considered acceptable in order to implement restoration actions beneficial to the long-term health of the estuaries intertidal marsh habitat. Thus, our final determination for this proposed restoration action is likely to have adverse affects initially, but has a long-term beneficial effect.

Cottonwood/Howard Island

The presence and use of Cottonwood/Howard Island by bald eagles is discussed in detail in the Columbia River Channel Improvement Project Biological Assessment and subsequent Biological Opinion. The reader or reviewer should reference these documents for full background information.

The proposed action to introduce Columbia white-tailed deer to Cottonwood/Howard Island and to monitor the introduced population for an undetermined period has the potential for insignificant disturbance to bald eagles. Potential disturbance actions are associated with transplant efforts and the presence of humans monitoring the population and health of the Columbia white-tailed deer population. Any disturbance related to transplant and/or monitoring activities would be spatially confined and of short duration. Cottonwood/Howard Island represents a foraging location for bald eagles. Their foraging activities are typically confined to the periphery of the islands along the beaches and riparian forest-water interface. Whereas, activities associated with Columbia white-tailed deer would be primarily in the interior of the island complex.

It is our determination that the proposed action at Cottonwood/Howard Island may affect, but is not likely to adversely affect, bald eagles.

Bachelor Slough

The Bachelor Slough proposal entails deepening an existing, silted in, side channel of the Columbia River and disposal of excavated material, either in-water or potentially on adjacent WDNR land. The WDNR lands (upland site) lie immediately downstream of the inlet for Bachelor Slough, outside the refuge boundary, in an area of historical dredged material disposal. Dredging and disposal of Bachelor Slough sediments is contingent upon sediment chemistry results that indicate contaminants are not an environmental issue. Disposal actions are also contingent upon securing an easement for upland disposal activities. The following discussion addresses both in-water and upland disposal on the adjacent WDNR lands.

Bachelor Slough bisects the Ridgefield National Wildlife Refuge near Ridgefield, Washington. Dredging activities would occur between two bald eagle territories: e.g., the Bachelor Island and Mallard Slough pairs, which occur near the inlet for Bachelor Slough (Isaacs and Anthony, 2001). The Bachelor Slough pair is sufficiently distant from the dredging locations in the slough to preclude disturbance to the pair at the nest from that activity. However, upland disposal (via pipeline dredge) on the adjacent WDNR lands would occur near the current nest site for the Bachelor Slough pair. The Mallard Slough pair's nest, although closer to the inlet for Bachelor Slough, appears to be sufficiently distant and screened by trees to preclude disturbance from dredging activities at the nest site.

Given the assumption that disposal actions would occur on the WDNR uplands downstream of the inlet for Bachelor Slough, then timing restrictions would have to be employed to ensure that the nesting pair is not disturbed. The likely time frame for dredging Bachelor Slough to accomplish this objective would then be August to October, inclusive. Given this timing premise, disturbance to the pair's nesting activities could be precluded.

Upland disposal on WDNR lands, particularly if sediments from Bachelor Slough have a relatively high silt content, are expected to result in the appropriate conditions for development of riparian forest habitat. Black cottonwoods would be expected to be the dominant tree component of any stand that develops. Black cottonwoods, over time, would provide a suitable nest tree for bald eagles. Thus, the potential exists to expand riparian forest, and therefore nesting habitat for bald eagles, with upland disposal of Bachelor Slough sediments.

Dredging and disposal actions are expected to result in localized disturbance to foraging bald eagles from these resident pairs. Such disturbance would be confined to an area immediately around the dredge and disposal site plus for a very short time frame when the discharge pipe is laid out between the dredge and disposal site. Given the limited area affected by dredging and disposal activities, plus the large area generally associated with a bald eagle territory, the disturbance imposed is not considered a significant impact. Alternate foraging areas are available throughout these bird's territories; thus, they will not be precluded from successfully foraging within their territories. In-water disposal (e.g., flowlane in or adjacent to the Columbia River navigation channel) would be sufficiently offshore as to preclude disturbance to foraging bald eagles.

Contaminants associated with the sediments in Bachelor Slough are undetermined at this time. However, prior to implementation of the action, sediment chemistry analyses will be conducted to determine the presence and level of contaminants. Implementation of the action is contingent upon sediment chemistry results that demonstrate that sediments are suitable for in-water and/or upland disposal. Otherwise, no action will be implemented.

It is our determination that the proposed action at Bachelor Slough may affect, but is not likely to adversely affect, bald eagles.

8.4.1.4 Marine Mammals, Excluding Northern Sea Lions

The FEIS incorporated by reference the ESA determinations for marine mammals and sea turtles, from the DMMP BA in their entirety as the two actions were considered identical relative to the listed species (Corps, 1999a, Section 6.7.2). However, ecosystem restoration features and research actions differ and, consequently, are assessed separately in this document. For more detailed background information on these listed marine mammals and sea turtles, see the DMMP BA.

The proposed ecosystem restoration features and research actions would have no effect on hump-backed, right, finback, sei, blue, or sperm whales, or on Pacific leatherback, loggerhead, green, or Pacific Ridley sea turtles. These species do not occur in the action areas for these restoration features or research actions.

8.4.1.5 Northern Sea Lions

Northern sea lions are not expected to occur in the vicinity of the Tidegate Retrofits, Cottonwood-Howard Island, and Shillapoo Lake ecosystem restoration features. Actions ERA-4, ERA-5 (Contaminants), and ERA-6 (ETM workshop) would occur off-river. Thus, these restoration features and research actions would have no effect on northern sea lions. Those restoration features and research actions, which have a potential to effect northern sea lions, are discussed below.

Lois Island Embayment Habitat Restoration

Northern sea lions may occur infrequently in the Lois Island Embayment when present in the Columbia River. They may occasionally forage in this embayment. Based on personal observation (Geoff Dorsey, Wildlife Biologist, Corps' Portland District), neither northern sea lions nor California sea lions have been observed in the embayment during the course of numerous visits across the seasons over a 20-year period (1981-2001). California sea lions have a heavily used haulout location a few miles downstream at the Astoria East Mooring Basin and are frequently observed in or adjacent to the main navigation channel at locations well upriver from this restoration feature area. The lack of observations in the embayment, coupled with frequent observations of California sea lions elsewhere in the river, would indicate that the embayment is not a preferred foraging area for either sea lion species. It is the Corps' determination that the proposed ecosystem feature may affect, but is not likely to adversely affect, northern sea lions.

Purple Loosestrife Control

Implementation of purple loosestrife control measures would occur in high elevation tidal marsh, likely during low tide. Northern sea lions inhabit deep, open water environments, not intertidal marsh habitat. Further, the only haulout for this species occurs on the south jetty of the Columbia River, well downstream of the proposed areas for feature implementation. Loosestrife control measures would use an herbicide that is EPA-registered for inwater application. Consequently, implementation of the purple loosestrife control feature would have no effect on northern sea lions.

Miller/Pillar Habitat Restoration

Northern sea lions may occur infrequently in or adjacent to the Miller/Pillar ecosystem restoration feature when they are present in the Columbia River. They may occasionally forage in or adjacent to the navigation channel, which abuts this restoration feature. Based on personal observation (Geoff Dorsey, Wildlife Biologist, Corps' Portland District), no northern sea lions have been observed in the Miller/Pillar restoration feature area during the course of numerous visits across the seasons over a 20-year period (1981-2001). California sea lions have been frequently observed in or adjacent to the main navigation channel at locations well upriver and downriver from this restoration feature area. Based on observations of California sea lions, we would expect the restoration feature area to provide a suitable foraging location for northern sea lions. All indications are that the number of northern sea lions present would be minimal.

The proposed feature entails the construction of a pile dike field and subsequent emplacement of dredged material to re-establish historical depths in the area to recapture the higher benthic invertebrate productivity and thereby increase the use and foraging quality of the area for juvenile salmonids. The two construction actions would be expected to result in temporary disturbances that would preclude northern sea lion use from their immediate vicinity. Given the extensive habitat area available to the species and the limited area impacted by the feature construction, northern sea lions can simply avoid the disturbance. It is our determination that the proposed action may affect, but is not likely to adversely affect, northern sea lions.

Tenasillahe Island Interim and Long-Term Restoration

Improving fish passage through implementation of tidegate improvements and increasing flows to these sloughs behind the main flood control levee has the potential for only a negligible amount of disturbance to northern sea lions. Similarly, the breaching of these levees, the long-term restoration feature, only poses a minor potential for disturbance to northern sea lions. Northern sea lions primarily occur in or adjacent to the main navigation channel. This proposed feature is off-channel and in backwater areas where northern sea lions are not expected to occur. It is our determination that the proposed action may affect, but is not likely to adversely affect, northern sea lions.

Lord/Walker and Fisher/Hump Embayment Restoration

Implementation of the Lord/Walker and Fisher/Hump embayment restoration features would occur off-channel. Each restoration feature would primarily entail the excavation of a channel in an upland setting, except where each channel is daylighted to the Columbia River and the embayment. Each feature is expected to take only a day or two to construct. The presence of northern sea lions in the restoration feature areas is unlikely, given the nature of the habitat (off-channel and upland). It is the Corps' determination that the proposed action may affect, but is not likely to adversely affect, northern sea lions.

Bachelor Slough

Implementation of this restoration feature would occur off-channel in a shallow side channel of the Columbia River. Bachelor Slough, near RM 93, lies well upstream of the normal incursion of northern sea lions into the Columbia River.

The proposed feature would be constructed using a small pipeline dredge with disposal occurring in an upland location adjacent to the Columbia River. Should northern sea lions occur in the project area, they would be expected to avoid the immediate area of the dredge. As the species is very mobile, they would be expected to move easily to a new location to continue their activities. The Columbia River offers the species abundant habitat; consequently, exclusion from a small area would have a negligible effect on northern sea lions.

Dredging of Bachelor Slough sediments is contingent on sediments not being contaminated. Contaminant levels will be determined prior to dredging implementation via testing by approved protocols. If contaminant levels in the sediments are outside established limits, the action will not be implemented.

It is the Corps' determination that the proposed feature may affect, but is not likely to adversely affect northern sea lions.

8.4.2 Ecosystem Research Actions

Six ESA Section 7(A)(1) ecosystem research actions have been proposed (see Table 8-1). Three actions (e.g., ERA-1, ERA-2 and ERA-4) involve physical (sampling) activities within the estuary. Action ERA-4 simply represents collection of fish while implementing ERA-1 and ERA-2 inventory actions. Action ERA-5 uses juvenile salmonids collected for Action ERA-4 and would occur in a laboratory setting. Action ERA-6 is a workshop on the ETM. Action ERA-3 is a bathymetric survey of the Columbia River estuary. Actions ERA-3, ERA-5 and ERA-6 have been determined to have no effect on any listed species under the purview of the Services. Action ERA-5 relies on fish sacrificed for Action ERA-4. Thus the effect is associated with Action ERA-4.

Actions ERA-1, -2, -3, and -4 have the potential to affect only three species under the purview of the USFWS, bald eagles, brown pelicans and coastal cutthroat trout. None of the other species under the Services purview, Columbia white-tailed deer, marbled murrelet, western snowy plover, Oregon silverspot butterfly, Howellia, golden paintbrush, Bradshaw's lomatium, Nelson's checkermallow, and bull trout are not expected to occur in the action area and therefore would not be affected by research implementation.

8.4.2.1 Federally Listed Salmonid ESUs, Excluding Coastal Cutthroat Trout and Bull Trout

Actions ERA-1, ERA-2, and ERA-4 would represent a take of listed stocks of juvenile salmonids. Constraints and requirements set forth by the NMFS for fisheries research actions involving listed stocks of juvenile salmonids will be adhered to by researchers. Research actions will be coordinated with and permitted by NMFS's Protected Resource Division, Portland, Oregon. Research proposals will be submitted that will indicate the listed stocks to be sampled, the number of fish anticipated to be handled and the number of fish required for sacrifice by ESU. Tabular information, published annually, lists predicted run sizes for various ESUs past specific geographical locations on the Columbia River. Using these projected run sizes and catch rate/efficiency of capture equipment, researchers will estimate the number of fish expected to be encountered during field research, percent of fish expected to be of wild stocks, and percent handling mortality. This and all other pertinent information relative to the permit requirements would be completed prior to field research implementation to the satisfaction of NMFS's Protected Resource Division.

Based on strict adherence to research protocols and permit requirements, it is our determination that the proposed action (Actions ERA-1, ERA-2, and ERA-4) may adversely affect and will result in a take of listed salmonids. However, the research action is intended to increase the knowledge base for these species to improve future management actions.

8.4.2.2 Coastal Cutthroat Trout and Bull Trout

Actions ERA-1, ERA-2, and ERA-4 would represent a take of juvenile coastal cutthroat trout. Bull trout will not be permitted to be collected, nor are they expected to occur in the area; thus, there will be no effect on the species. Research objectives will be set in accordance with biological information needs. Take of coastal cutthroat trout will be limited to a discrete sample size, determined in conjunction with USFWS representatives. Whether coastal cutthroat trout will be collected for sacrifice will also be determined in conjunction with Service biologists. The necessary permits for take will be acquired prior to field implementation of research and research protocol will be coordinated with and approved by the Service.

8.4.2.3 Bald Eagle

Actions ERA-1 through ERA-4 will occur in bald eagle habitat. All but ERA-3 entail activities along specified field transects in the Columbia River estuary, including transects upstream of RM 35. Action ERA-3 is a bathymetric survey of the entire Columbia River estuary.

Based on the historical data base detailing bald eagle nesting locations in the Columbia River estuary, plus future year bald eagle occupancy and productivity surveys that the Corps has committed to funding, transect locations can be regulated to preclude disturbance to nesting bald eagles. Occasional disturbance to foraging bald eagles may result from research activities along transects but such disturbance is expected to be temporally and spatially restricted. While foraging bald eagles may be temporarily excluded from a portion of their territory, these territories are sufficiently large that alternative foraging locations will be available to bald eagles.

The bathymetric survey effort will also result in incursions into bald eagle habitat. This activity would be anticipated to occur from a relatively small boat in the shallow water and flats habitat where bald eagles would be expected to occur. Further, surveys of tidal flats would be anticipated to occur primarily during high tides when bald eagle use of these areas is typically low. Constantly moving boats represent an insignificant disturbance potential to bald eagles as they soon move out of the area. Human presence is therefore limited and the perception of danger by bald eagles appears to be minimized. Knowledge of bald eagle nesting locations will be used to further ensure that researcher activity around nest sites is greatly minimized or eliminated.

Thus, it is the Corps' determination that Actions ERA-1 through ERA-4 may affect, but are not likely to adversely affect, bald eagles.

8.4.2.4 Brown Pelican

Actions ERA-1, ERA-3 and ERA-4 have the potential to affect brown pelicans. Disturbance potential associated with ERA-1 and ERA-4 is considered very minimal as few, if any, transects are likely to be placed in areas of the estuary (Columbia River mouth, East Sand Island, Baker Bay) where brown pelican concentrations develop. East Sand Island and pile dikes around East Sand/West Sand Island and the Chinook channel entrance support the largest concentrations of brown pelican, principally from mid-May to October with the largest presence during July-September. Actions ERA-1 and ERA-4, particularly if they do not include the shorelines of East Sand Island, have an insignificant disturbance effect on brown pelicans. Bathymetric surveys, if they approach within 100 yards of the shoreline of East Sand Island, would result in the flushing of large concentrations (more than 2,000 birds) of brown pelicans. To avoid such circumstances, bathymetric surveys would be implemented when brown pelicans are not present.

Thus it is the Corps' determination that the proposed action may affect, but is not likely to adversely affect, brown pelicans.

8.4.2.5 Northern Sea Lions

Action ERA-1 would add additional transects (one or two) to the research effort being conducted for NMFS under AFEP. Research actions along each transect are spatially limited to a small area and are short term in nature during each survey period. Given the extensive habitat area available to the species in either the estuary or river proper, and the limited area impacted by the research action, northern sea lions can simply avoid the disturbance. It is the Corps' determination that the proposed action may affect, but is not likely to adversely affect, northern sea lions.

Action ERA-2 would add one additional transect upstream of RM 35 to the research effort being conducted for NMFS under AFEP. Research actions along each transect are spatially limited to a small area and are short term in nature during each survey period. Given the extensive habitat area available to the species in the river proper, and the limited area impacted by the research action, northern sea lions can simply avoid the disturbance. It is the Corps' determination that the proposed action may affect, but is not likely to adversely affect, northern sea lions.

Action ERA-3 is a bank-to-bank hydrographic survey of the Columbia River estuary. Hydrographic surveys are typically conducted using survey boats traversing specific survey lines. Boats thus run along a steady heading at a steady speed. There is a small probability of encounters with northern sea lions during the course of these surveys. Sea lion reaction to an encounter with a boat is to dive and move a short distance from the boat's course before resuming normal activities. Such encounters are short-lived, typically less than 30 seconds. These disturbance actions do not constitute a threat to the survival of northern sea lions. It is the Corps' determination that the proposed action may affect, but is not likely to adversely affect, northern sea lions.

Action ERA-4 entails the collection for further scientific study of juvenile salmonids collected during execution of research Actions ERA-1 and ERA-2. No additional disturbance to northern sea lions would result because of implementation of this action. It is our determination that the proposed action may affect, but is not likely to adversely affect, northern sea lions.

8.5 Conclusion

Under this BA, the Corps has modified the project to include these ecosystem restoration and research actions allowed at its discretion under Section 7(a)(1) of the ESA. These actions will restore and improve the habitat and increase knowledge of listed and candidate salmonid species as well as other native species found in the lower Columbia River ecosystem.   The area, type, value, and function for each feature are listed in Table 8-2. The Corps will develop detailed proposals, which will be coordinated with the Services, and then work to implement them using the process described in Section 9.2, Adaptive Management Process.

Table 8-2: Ecosystem Restoration Features for the Project

Feature	Area Affected by Restoration (acres)	Type, Function, and Value
Lois Island Embayment Habitat Restoration	389	Type: Tidal marsh and swamp; shallow water and flats habitat Function: Provide rearing habitat for ocean-type salmonids; increase detrital export Value: High
Purple Loosestrife Control Program	300	Type: Tidal marsh and swamp Function: Maintain native Tidal marsh plant community; increase detrital export Value: High
Miller/Pillar Habitat Restoration	161	Type: Shallow water and flats habitat Function: Provide rearing habitat for ocean-type salmonids; increase benthic invertebrate productivity Value: High
Tenasillahe Island Interim Restoration[1] (Tidegate/Inlet Improvements)	92	Type: Backwater/side channel reconnection to Columbia River Function: Increase access/egress for ocean-type salmonids Value: Moderate
Tidegate Retrofits for Salmonid Passage	38 miles	Type: Tributary reconnection to Columbia River Function: Increase access/egress for ocean-type salmonids; improve access for adult salmonids to headwaters for spawning Value: High
Walker/Lord and Hump/Fisher Islands Improved Embayment Circulation	335	Type: Marsh and swamp; shallow water and flats habitat Function: Provide rearing habitat for ocean-type salmonids; increase benthic invertebrate productivity Value: Moderate
Martin Island Embayment	32	Type: Tidal marsh and swamp (wildlife mitigation) Function: Increase detrital export; provide rearing habitat for ocean-type salmonids Value: Moderate (salmonids); high (wildlife)
Cottonwood/Howard Island Proposal[2] Columbia White-Tailed Deer Introduction	1,000	Type: Translocation of Columbia white-tailed deer Function: Establish secure, viable subpopulation of Columbia white-tailed deer Value: High
Tenasillahe Island Long-Term Restorations[3] (Dike Breach)	1,778	Type: Tidal marsh and swamp; shallow water and flats habitat Function: Provide rearing habitat for ocean-type salmonids; increase detrital export Value: High
Bachelor Slough Restoration[4]	300 (instream restoration) 6 (shoreline) 27 (riparian restoration)	Type: Shallow water and flats habitat; riparian forest Function: Provide rearing habitat for ocean-type salmonids; increase detrital export Value: Moderate (side channel); high (riparian forest)
Shillapoo Lake Restoration[5]	1,250 acres	Type: Managed wetlands Function: Increase waterfowl, shorebird, wading bird, and raptor habitat Value: High
Notes: The Tidegate Retrofits for Salmonid Passage, Walker/Lord and Hump/Fisher Islands Improved Embayment Circulation, and Shillapoo Lake Restoration features were proposed in the original FEIS (Corps, 1999a). The remaining restoration features were added during the BA reconsultation process. [1]This restoration is contingent on hydraulic analysis results. [2]This restoration primarily benefits Columbia white-tailed deer. [3]This restoration feature is contingent on the delisting of Columbia white-tailed deer. [4]This restoration primarily benefits waterfowl, but would create detrital input to the Columbia River. [5]This restoration feature is contingent on sediment testing and approval by WDNR. .		

9 AN ECOSYSTEM APPROACH TO PROJECT IMPLEMENTATION USING AN ADAPTIVE MANAGEMENT PROCESS

9.1 Introduction

Section 7 of this BA details conservation actions that will be taken to avoid and minimize project impacts and take of the listed and candidate salmonid species and habitats found in the action area. It also addresses monitoring actions that will be taken to ensure that the proposed Project minimizes and/or avoids a take of a listed species or adverse effect on their habitat. Section 8 of this BA describes ecosystem restoration and research actions that are proposed by the Corps to be added to the proposed action. These actions were selected to complement regional initiatives already under way within the Columbia River Basin and are designed to be implemented in collaboration with regional goals. These actions will restore valuable habitat and contribute to the knowledge base necessary to advance the recovery of threatened and endangered aquatic species in the lower Columbia River ecosystem. All of these actions address indicators found in the conceptual model developed for salmonids (see Section 5).

Table 9-1 lists the Project actions that address specific conceptual model indicators. This table displays the compliance, monitoring, research, and restoration actions that the proposed Project will implement, addressing a significant portion of the indicators and, therefore, questions related to the lower Columbia River ecosystem as described in the conceptual model (see Section 5, Current System Function). Table 9-2 shows the purpose and timeline for monitoring and adaptive management actions proposed for the Project.

9.2 Adaptive Management Process

The Corps recognizes that implementation of the proposed monitoring, compliance, restoration, and research actions will be most effective using an ecosystem approach that recognizes a multiplicity of scales. This will assist the other entities in the region involved in restoring the Columbia River estuary to advance the state of knowledge for salmonid recovery, make ecosystem improvements, and conduct research in a collaborative effort. The Corps, Sponsor Ports (as long as funding involves the Ports for the Project), and the Services will be the adaptive management team and will collaborate in decision making for changes to the project. The Corps will perform the proposed actions using an adaptive management approach for the life of the Project, as described below.

Adaptive management is an iterative approach to managing ecosystems, where the methods of achieving the desired objectives are unknown or uncertain (Holling, 1978). Adaptive management is a continuous process of action based on doing, learning, sharing, and improving (BC Ministry of Forestry and USDA Forest Service) (see Figure 9-1). Adaptive management recognizes there are multiple explanations about biological processes and uncertainty. An important feature of the adaptive management approach is incorporating this uncertainty into the decision-making process. The decision process can modify the action, monitoring, or research, thereby reducing uncertainty and improving environmental management through monitoring.

The first step to adaptive management is to plan and set directions, and to determine objectives. The conceptual model can be used to establish hypotheses of connections between the proposed action and species of concern, and it provides a basis for clarifying assumptions and organizing the monitoring and adaptive management plan.

The proposed construction of the channel improvements includes a comprehensive monitoring plan (see Sections 7 and 8) that includes a range of monitoring actions. Monitoring will gather information to evaluate predicted effects, validate assumptions, and reduce risk and uncertainty. The adaptive management and monitoring plan requires establishment of clearly stated goals, specific metrics, and management decision points. Management decision points are identified as part of the adaptive management plan. An essential component will be to evaluate whether management goals are being met and adjust actions to move closer to agreed-on goals.

9.3 Adaptive Management for the Project

The adaptive management team will consist of the Corps, the Services, and the Sponsor Ports. The team will carry forward the hierarchical structure that has functioned through this reconsultation to have equal participation from the project management level, within the management structure, and the regional executives of the three agencies and the ports. It is envisioned that this group will continue to function through the duration of the monitoring actions prescribed. The group will be the decision-making body to make modifications to project actions, compliance measures, monitoring program, research, and ecosystem restoration features.

The Corps anticipates working with the Services to further refine and develop the monitoring and adaptive management plan, including clear goals and scope.

Some aspects of the adaptive management process that will be incorporated include:

- An annual review meeting for monitoring, research, and restoration actions
- A review of compliance actions at each finding of adverse effect
- Monitoring program information available to the public
- An annual review and decision regarding monitoring, research, and restoration actions, and related compliance actions, to be conducted by the Corps, Sponsor Ports, and the Services.

9.3.1 No Effects Indicated

At each annual meeting of the AMT, monitoring, research, or restoration activities will be reviewed and evaluated. If no impact is found, and/or no new information is identified, the AMT will decide whether the action should be adjusted and continued (time/duration and scale will be reviewed). The AMT will decide on whether to stop all or part of the monitoring action, based on input from the entities conducting the field work.

Finally, the AMT will decide if the monitoring and field data collection is to be continued for an additional year, and whether it would still be appropriate to fund under this project.

9.3.2 Effects Indicated

If an impact is found, or the action is not implemented as proposed, or new information is found, the AMT has numerous options available. These options range from the project construction or operation remaining the same to stopping the project. Additionally, the AMT could decide that the restoration features should be altered or that the action should be stopped until more data are collected and assessed.

Options, in hierarchical order, follow:

- Project construction and operation remain the same.
- Project construction and operation remain the same. Restoration features are increased.

- Project construction is altered.
- Project construction is stopped until more data are collected.
- Project construction is stopped.

9.4 Conclusion

This Project will be performed using an ecosystem approach based on adaptive management. Actions associated with dredging and disposal [Section 7 (a) (2)] and ecosystem restoration and research actions [Section7 (a) (1)] will be coordinated through the adaptive management process to ensure that the project will not jeopardize listed or proposed species or destroy or adversely modify their critical habitat.

Table 9-1 – Conceptual Model Indicators Addressed by Project Actions[19]

Pathway	*ESA Section 7(a)(2)*		*ESA Section 7(a)(1)*	
	Compliance Actions	**Monitoring Actions**	**Research Actions**	**Restoration Actions**
Habitat-Forming Processes				
Suspended Sediment				
Bedload		MA-2		
Woody Debris				
Turbidity				
Salinity		MA-1	ERA-6	
Accretion/Erosion		MA-2, MA-3		
Bathymetry		MA-1, MA-3	ERA-3	
Habitat Types				
Tidal Marsh and Swamp		MA-4	ERA-1, ERA-2	Yes[20]
Shallow Water and Flats	CA-8	MA-3, MA-4	ERA-1, ERA-2, ERA-3	Yes[21]
Water Column	CA-9, CA-10		ERA-1, ERA-2	
Primary Productivity				
Light				
Nutrients				

[19] References in this table to " MA-#, CA-#," and "ERA-#" are to action numbers provided in Tables 7-2, 7-3, 7-5, 7-6, and 8-1.
[20] Location to be determined.
[21] Location to be determined.

Pathway	*ESA Section 7(a)(2)*		*ESA Section 7(a)(1)*	
	Compliance Actions	**Monitoring Actions**	**Research Actions**	**Restoration Actions**
Imported Phytoplankton Production				
Resident Phytoplankton Production				
Benthic Algae Production				
Tidal Marsh Production				
Food Web				
Deposit Feeders	CA-4	CA-4		
Mobile Macroinvertebrates	CA-4			
Insects		MA-4		
Suspension/Deposit Feeders	CA-4			
Suspension Feeders		MA-4		
Tidal Marsh Macrodetritus		MA-4		
Resident Microdetritus				
Imported Microdetritus				
Growth				
Habitat Complexity	CA-4, CA-6	MA-1, MA-4		
Velocity Field		MA-1		
Bathymetry and Turbidity	CA-2, CA-3, CA-4			
Feeding Habitat Opportunity	CA-4	MA-1, MA-4		

Pathway	*ESA Section 7(a)(2)*		*ESA Section 7(a)(1)*	
	Compliance Actions	**Monitoring Actions**	**Research Actions**	**Restoration Actions**
Refugia	CA-6	MA-4		
Habitat-Specific Availability	CA-6	MA-4		
Survival				
Contaminants	CA-5, CA-7	MA-5	ERA-4, ERA-5	
Disease				
Suspended Solids	CA-2, CA-3			
Stranding		MA-6		
Temperature and Salinity Extremes		MA-1		
Turbidity	CA-2, CA-3			
Predation				
Entrainment	CA-1			

Table 9-2 – Monitoring and Adaptive Management Actions for the Columbia River Channel Improvements Project

	Action	ESA Section 7	Purpose for Monitoring	Time Frames for Review
	Compliance	7(a)(2)	Precautionary Anticipate emergencies Avoid and minimize effects Verify assumptions	Upon an adverse finding
Monitoring	Risk and Uncertainty Monitoring	7(a)(2)	Precautionary Anticipate emergencies Trends Advance scientific knowledge	Annual Cumulative data review
Monitoring	Effects Monitoring	7(a)(2)	Precautionary Anticipate emergencies Trends Advance scientific knowledge	Annual
Monitoring	Validation of Assumptions	7(a)(2)	Develop/calibration of models Research Advance scientific knowledge	Annual
	Research	7(a)(1)	Trends Collaboration with regional goals Research Advance scientific knowledge	Annual
	Restoration and Associated Monitoring	7(a)(1)	Research Trends Advance scientific knowledge	Annual

Figure 9-1: Continuous Management – Columbia River Channel Improvements Project

10 DETERMINATION OF NEED FOR FORMAL CONSULTATION AND CONFERENCE

The purpose of a BA is to provide information from the action agency, in this case the Corps, to determine whether it should engage in formal consultation with the Services. The Services' Consultation Handbook explains that whenever a project has any components that are likely to adversely affect listed species and habitat, formal consultation is required, even if other components of the project, or in fact the project as a whole, benefit the species.

The effects analysis in Section 6 has identified a limited potential for dredging and disposal operations to adversely affect listed species. This potential is addressed by use of BMPs that are expected to eliminate or minimize potential adverse effects on the listed species. Any potential take of the species will be further addressed by an incidental take statement from the services.

The Project could affect shallow water and flats habitat in several potential ways. First, side-slope adjustments associated with channel deepening may cause a shift in the location of shallow water habitats associated with past beach nourishment sites. Side-slope adjustment will occur over a period of 5 to 10 years. This process will cause shallow water and flats habitat at six historical shoreline disposal sites to migrate laterally; however, the quantity and quality of shallow water and flats habitat is expected to remain constant. Second, shoreline disposal for beach nourishment will result in the placement of dredge materials in shallow water habitats at three locations. However, the three shoreline disposal sites are all highly erosive and do not contain many of the important habitat features that shallow water habitats typically include, such as low velocity, vegetation, and food sources. All three sites had previously been approved by NMFS for shoreline disposal because of their low productivity. Third, changes in water surface elevation have been evaluated to determine whether a potential exists for habitat opportunity to be reduced within shallow water areas. Water surface elevation could be affected between RM 80 and RM 146. The decrease could be up to 0.18 foot (approximately 2 inches) at the upstream end of the project.

A monitoring program and adaptive management process has been incorporated into the project to address uncertainty and risks identified in the BA.

The Project includes ecosystem restoration features intended to produce long-term benefits for listed species and their habitat. These features are discussed in Sections 3 and 8. The function and value of these projects is summarized in Table 8-2. These features include restoration of tidal habitat, restored access to stream rearing and important intertidal habitat, and significant reduction of invasive Purple loosestrife.

Based on the guidance in the Consultation Handbook, the Services' Consultation Regulations and Section 7 of the ESA, the Corps has determined that it is appropriate to request formal consultation for the 13 listed salmonid species, one proposed and one candidate species and marine mammals. The Corps will request USFWS confirmation that the existing BO for terrestrial species is still in effect, and will request the Services' consultation and conference on the proposed action. Reasons for requesting formal consultation and conferencing include:

- Although the dredging and disposal portion of the Project includes best management practices to address potential effects, the possibility remains that there may be some incidental take of species. Any incidental take, no matter how unlikely or small, would be an adverse effect that warrants formal consultation. In addition, it is important to engage in formal consultation that results in a biological opinion and a conference opinion that include incidental take statements that cover potential take.

- The BA identifies specific areas where there are uncertainties and risks. The conclusions regarding uncertainties and risks are based on the SEI process and considerable discussion with the Services. The Corps believes that it is important for this information to be confirmed and for the commitments to monitoring and adaptive management be reflected in a biological opinion.
- The Project includes an Ecosystem Restoration Component. This component includes activities that will have beneficial effects on listed species and their habitat and that will benefit a variety of terrestrial species. Through the reconsultation process, the Corps has added the restoration actions discussed in Section 8 to the Project. Formal consultation allows the Services to review the proposed Ecosystem Restoration features.

11 ACRONYMS AND ABBREVIATIONS

Acronym	Definition
AMT	Adaptive Management Team
BA	Biological Assessment
BMP	Best Management Practices (see Glossary)
BO	Biological Opinion
BRT	Biological Review Team
BSAF	Biota-sediment accumulation factor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic feet per second
CITES	the 1973 Convention on International Trade in Endangered Species
Cm	Centimeter
Corps	U.S. Army Corps of Engineers
CPUE	Catch per unit effort
CRD	Columbia River datum
CREDDP	Columbia River Estuary Data Development Program
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DDT	Dichlorodiphenyl trichloroethane
DMMP	Dredged Material Management Plan
DPS	Distinct Population Segment
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERA	Ecosystem Research Action

ESA	Endangered Species Act of 1973, as amended 16 U.S.C. 1513 et seq
ESUs	Evolutionary Significant Units
ETM	Estuarine Turbidity Maximum
FEIS	Final Environmental Impact Statement
g/L	Grams per liter
HEP	Habitat Evaluation Procedure
HMG	Habitat Managagement Goal
ISAB	Independent Scientific Advisory Board
km	Kilometer
LAA	Likely to Adversely Affect
LC_{50}	Lethal concentration for 50 percent of a population
LCREP	Lower Columbia River Estuary Program
MCR	Mouth of the Columbia River
mcy	Million cubic yards
mg/L	Milligrams per liter
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
mm	Millimeters
NE	No Effect
NEPA	National Environmental Policy Act
NLAA	May Effect, Not likely to Adversely Affect
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOEC	No observed effect concentration
NPL	National Priorities List (Superfund)
NRC	National Research Council

NTU	Nephelometric turbidity unit
ODMDS	Ocean dredged material disposal sites
O&M	Operations and Maintenance
OHSU/OGI	Oregon Health and Science University/Oregon Graduate Institute
PAH	Polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PFC	Properly Functioning Conditions
ppb	Parts per billion
ppt	Parts per thousand
psi	Pounds per square inch
RM	River Mile
RPG	Recovery population goal
RZ	Recovery Zone
SEDQUAL	Sediment Quality Information System (a regional sediment database)
SEI	Sustainable Ecosystems Institute
SEPA	State Environmental Policy Act
Services	NMFS and USFWS
$\sum$	Total (e.g., $\sum$PCBs – total polychlorinated biphenyls)
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WES	Waterways Experiment Station
WSDOE	Washington State Department of Ecology
YOY	Young of the Year

12 GLOSSARY

The definitions in this list have no legal significance, and are provided only for clarification of terms used throughout this document.

Term	Definition
Acclimation temperature	The temperature at which fish have been held for a period of days prior to being subjected to experimental temperature changes.
Accretion	Slow settling of sediments from suspension in back waters and slower moving waters.
Act	The Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 *et seq*
Action	All activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States or upon the high seas. Examples include, but are not limited to: (a) actions intended to conserve listed species or their habitat; (b) the promulgation of regulations;(c) the granting of licenses, contracts, leases, easements, rights-of-way, permits, or grants-in-aid; or (d) actions directly or indirectly causing modifications to the land, water, or air. [50 CFR §402.02]
Action area	All areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action. [50 CFR §402.02]
Adaptation	Structural, physiological, or behavioral characteristics which help an organism fit its habitat and living requirements.
Adfluvial	Refers to a lake. Potential feeding habitat for migrating Coastal cutthroat trout.
Advance maintenance dredging	Advance maintenance dredging provides year-round channel availability through an annual program of dredging.
Adult Salmon	A salmon that is at least two years old and usually three years or older, that is near or has reached sexual maturity.
Affect/Effect	To affect is to bring about a change ("the proposed action is likely to adversely affect piping plovers nesting on the shoreline"). the effect is the result ("the proposed action is likely to have the following effects on the listed salmonids"). **"Affect"** appears throughout Section 7 consultation documents and guidelines in phrases such as, "may affect" and "likely to adversely affect." **"Effect"** appears throughout Section 7 consultation documents and guidelines in the phrases "adverse effects," "beneficial effects," "effects of the action," and "no effect."
Alevin	The first post-hatch life stage of salmon. Alevins will have some portion of their yolk sac showing on their abdomen. A life stage commonly found only within spawning gravel or hatcheries.
Algae	Simple plant forms having no true roots, stems or leaves. Algae range in size from microscopic single-celled plants to large seaweeds.
Algal bloom/Harmful	Most species of algae or phytoplankton are not harmful and serve as the energy

Algal Bloom (HAB)	producers at the base of the food web, without which higher life on this planet would not exist. Occasionally, the algae grow very fast or "bloom" and accumulate into dense, visible patches near the surface of the water. A small number of species produce potent neurotoxins that can be transferred through the food web where they affect and even kill the higher forms of life such as zooplankton, shellfish, fish, birds, marine mammals, and even humans that feed either directly or indirectly on them. Scientists now prefer the term, HAB, to refer to bloom phenomenon that contain toxins or that cause negative impacts.
Alluvial	Deposited by running water
Amphipod	Invertebrate animal of the crustacean class. Amphipods are characterized by laterally flattened bodies and include sand fleas and related forms.
Anadromous	Fish that hatch in fresh water, migrate to seawater as juveniles, and return to spawn in fresh water as adults.
Anaerobic	A condition in which molecular oxygen is absent (or effectively so) from the environment.
Anthropogeneic	Man made or man caused.
Anticipated / allowable / authorized	In Incidental Take statements, the Services determine the amount or extent of incidental take "anticipated" (expected) due to the proposed action or an action modified by reasonable and prudent alternatives. When writing incidental take statements, use only the phrase "anticipated" rather than "allowable" or "authorized," as the Services do not allow or authorize (formally permit) incidental take under section 7
Applicant	Any person (an individual, corporation, partnership, trust, association, or any other private entity; or any officer, employee, agent, department, or instrumentality of the Federal Government, of any State, municipality, or political subdivision of a State, or of any foreign government; any State, municipality, or political subdivision of a State; or any other entity subject to the jurisdiction of the United States) [ESA §3(12)] who requires formal approval or authorization from a Federal agency as a prerequisite to conducting the action. [50 CFR §402.02]
Aquatic ecosystem	Any body of water, such as a stream, lake or estuary, and all organisms and nonliving components within it, functioning as a natural system.
Aquatic habitat	The water-based geographic area and all the ecosystem components within it, in which a particular plant or animal species or species group naturally live, or in which all their life requisites are satisfied.
Ash-free dry weight (AFDW)	The dehydrated tissue weight after hard tissues, such as shells, have been removed.
at-risk fish stocks	Stocks of anadromous salmon and trout that have been identified by professional societies, fish management agencies, and in the scientific literature as being in need of special management consideration because of low or declining populations.

Basalt	The commonest type of solidified lava. A hard, dense, dark volcanic rock.
Bathymetry	Topographical (surface) configuration of the riverbed.
Beach nourishment disposal sites	Shoreline fills that replace eroded material. See also shoreline disposal.
Bed material	Sediments composing the riverbed
Bedform	Sediment bottom feature often resembling a sand ripple or a small sand dune.
Bedload	The movement of sand grains rolling and bouncing along the surface of the riverbed. In sandy riverbeds, bedload transport shapes the bed into a series of sandwaves.
Benthic	An environment or habitat related to the bottom of a stream or body of water.
"Best available scientific and commercial data"	To assure the quality of the biological, ecological, and other information used in the implementation of the Act, it is the policy of the Services to: (1) evaluate all scientific and other information used to ensure that it is reliable, credible, and represents the best scientific and commercial data available; (2) gather and impartially evaluate biological, ecological, and other information disputing official positions, decisions, and actions proposed or taken by the Services; (3) document their evaluation of comprehensive, technical information regarding the status and habitat requirements for a species throughout its range, whether it supports or does not support a position being proposed as an official agency position; (4) use primary and original sources of information as the basis for recommendations; (5) retain these sources referenced in the official document as part of the administrative record supporting an action; (6) collect, evaluate, and complete all reviews of biological, ecological, and other relevant information within the schedules established by the Act, appropriate regulations, and applicable policies; and (7) require management-level review of documents developed and drafted by Service biologists to verify and assure the quality of the science used to establish official positions, decisions, and actions taken by the Services during their implementation of the Act. [59 FR 34271 (July 1, 1994)]
"Best Management Practices" (BMPs)	Methods, measures, or practices designed to prevent or reduce water pollution. Not limited to structural and nonstructural controls, and procedures for operations and maintenance. Usually, BMPs are applied as a system of practices rather than a single practice.
Biodiversity	The variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.
Biological Assessment	Information prepared by, or under the direction of, a Federal agency to determine whether a proposed action is likely to: (1) adversely affect listed species or designated critical habitat; (2) jeopardize the continued existence of species that are proposed for listing; or (3) adversely modify proposed critical habitat. Biological assessments must be prepared for "major construction activities." See 50 CFR §402.02. the outcome of this biological assessment determines whether formal consultation or a conference is necessary. [50 CFR §402.02, 50 CFR §402.12]

Biological Opinion	Document which includes: (1) the opinion of the Fish and Wildlife Service or the National Marine Fisheries Service as to whether or not a Federal action is likely to jeopardize the continued existence of listed species, or result in the destruction or adverse modification of designated critical habitat; (2) a summary of the information on which the opinion is based; and (3) a detailed discussion of the effects of the action on listed species or designated critical habitat. [50 CFR §402.02, 50 CFR §402.14(h)]
Biomass	The amount of a living group of organisms in a given habitat, expressed either as the weight of organisms per unit area, or as the volume of organisms per unit volume of habitat.
Brackish	Pertaining to water with a salt content ranging between that of sea water and fresh water. Especially used to describe the tidally-influenced mixture of seawater and freshwater.
Broodstock	Adult salmon that provide the embryos that form the next generation.
Candidate Conservation Agreement with Assurances	Voluntary agreements that provide non-Federal property owners who agree to manage their lands or waters to remove threats to candidate or proposed species assurances that their conservation efforts will not result in future regulatory obligations in excess of those they agree to at the time they enter into the agreement.
Candidate species	Plant and animal taxa considered for possible addition to the List of Endangered and Threatened Species. These are taxa for which the Fish and Wildlife Service has on file sufficient information on biological vulnerability and threat(s) to support issuance of a proposal to list, but issuance of a proposed rule is currently precluded by higher priority listing actions. [61 FR 7596-7613 (February 28, 1996)]
Cape-size vessel	A type of deep-draft bulk ship carrying 100,000 to 175,000 tons.
Carnivore	A flesh eating animal.
Cataclysmic	The characteristic of a violent geological upheaval that causes great destruction or brings about a fundamental change in the landscape. A cataclysmic event may result in a violent and sudden change in the earth's crust. A devastating flood
Cephalopods	Any of various marine mollusks of the class Cephalopoda, such as the octopus, squid, cuttlefish, or nautilus, having a large head, large eyes, prehensile tentacles, and, in most species, an ink sac containing a dark fluid used for protection or defense.
Channel improvements	Channel widening or channel realignment measures to attain navigation safety and efficiency.
Channel Reaches	See River reach/Stream reach.
Chironomids	Midges, a Family of Dipterans (flies) with aquatic larvae and provides a common food source for young chinook and other fishes.
Chum salmon	A Species of salmonids (*Oncorhynchus keta*) that has the widest distribution of any of the Pacific salmon. Chum salmon are the most abundant commercially harvested salmon species in arctic, northwestern, and Interior Alaska, but are of relatively less

	importance in other areas of the state.
Cladoceran	Invertebrate animal of the crustacean class. Cladocerans are often called water fleas.
Clamshell dredging	Clamshell dredges use a bucket operated from a crane or derrick that is mounted on a barge or operated from shore. Sediment removed by the bucket is usually placed on a barge for disposal to either an upland or in-water site.
Climatological	Related to or resulting from long term weather conditions
Cobble	Stones of about 5-15 cm (2-6 inches) diameter.
Columbia River Datum (CRD)	The Columbia River navigation channel elevations are referenced to the Columbia River Datum established in the 1930s. the CRD is a local datum based on observed water surface elevations during low discharge-low tide conditions.
Conceptual Model	A graphic diagram designed to visually represent the holistic, complex relationships with a functioning system.
Conference	A process of early interagency cooperation involving informal or formal discussions between a Federal agency and the Services pursuant to section 7(a)(4) of the Act regarding the likely impact of an action on proposed species or proposed critical habitat. Conferences are: (1) required for proposed Federal actions likely to jeopardize proposed species, or destroy or adversely modify proposed critical habitat; (2) designed to help Federal agencies identify and resolve potential conflicts between an action and species conservation early in a project's planning; and (3) designed to develop recommendations to minimize or avoid adverse effects to proposed species or proposed critical habitat. [50 CFR §402.02, 50 CFR §402.10]
Confluence	The point or area at which separate streams or currents meet and run together.
Conservation	The terms "conserve," "conserving" and "conservation" mean to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to [the] Act are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resources management such as research, census, law enforcement, habitat acquisition and maintenance, propagation, live trapping, and transplantation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking. [ESA §3(3)]
Conservation measures	Are actions to benefit or promote the recovery of listed species that are included by the Federal agency as an integral part of the proposed action. These actions will be taken by the Federal agency or applicant, and serve to minimize or compensate for, project effects on the species under review. These may include actions taken prior to the initiation of consultation, or actions which the Federal agency or applicant have committed to complete in a biological assessment or similar document.
Conservation plan	Under section 10(a)(2)(A) of the ESA, a planning document that is a mandatory component of an incidental take permit application, also known as a Habitat Conservation Plan or HCP.

Conservation recommendations	The Services' non-binding suggestions resulting from formal or informal consultation that: (1) identify discretionary measures a Federal agency can take to minimize or avoid the adverse effects of a proposed action on listed or proposed species, or designated or proposed critical habitat; (2) identify studies, monitoring, or research to develop new information on listed or proposed species, or designated or proposed critical habitat; and (3) include suggestions on how an action agency can assist species conservation as part of their action and in furtherance of their authorities under section 7(a)(1) of the Act. [50 CFR §402.02]
Constituent elements	Physical and biological features of designated or proposed critical habitat essential to the conservation of the species, including, but not limited to: (1) space for individual and population growth, and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and (5) habitats that are protected from disturbance or are representative of the historic geographic and ecological distributions of a species. [ESA §3(5)(A)(i), 50 CFR §424.12(b)]
Convention on International Trade in Endangered Species (CITES)	A 1973 agreement restricting international commerce between participating nations for plant and animal species believed to be harmed by trade.
Copepod	Invertebrate animal of the crustacean class. Copepods are abundant members of the zooplankton.
Critical habitat	Under the Endangered Species Act, critical habit is defined as (1) the specific areas within the geographical area occupied by a federally listed species on which are found physical and biological features essential to the conservation of the species, and that may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by a listed species, when it is determined that such areas are essential for the conservation of the species.
Crustacean	A class of the arthropod phylum that includes, among others, crabs, water fleas, barnacles, and shrimp.
Cubic feet per second (cfs)	A unit of measurement pertaining to flow or discharge of water. One cfs is equal to 449 gallons per minute.
Cumulative effects	Under the ESA, those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation. [50 CFR §402.02] This definition applies only to Section 7 consultation analyses and should not be confused with the broader use of this term in the National Environmental Policy Act or other environmental laws.
Cumulative effects (NEPA)	Under NEPA, the incremental environmental impact or effect of the action together with impacts of past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions. (40 CFR 1508.7)
Cut bank	A steep stream bank, commonly undercut by the stream current, provides holding or

	refuge habitat for fish.
Cutline shoals	Cutline shoals form along the edges of the navigation channel where steep-sided slopes from the dredging cause bedload to be deflected into the channel, forming new shoals. Over time, this action will cause the side-slope adjacent to a dredge cut to degrade until an equilibrium slope is re-established. In many places the side-slope degradation extends for hundreds of feet out from the navigation channel.
Deep-draft vessels	Vessels with over 15 foot draft, i.e., vessels immersed in water to a depth of at least 15 feet.
Delist	To remove from the Federal list of endangered and threatened species (50 CFR 17.11 and 17.12) because such species no longer meets any of the five listing factors provided under section 4(a)(1) of the ESA and under which the species was originally listed (i.e., because the species has become extinct or is recovered).
Demersal	Pertaining to an organism, such as a fish, living close to or on the bottom of a body of water.
Density	(a) the number of organisms per unit of area (for example, animals per square meter); (b) the weight of a substance, such as water per unit of volume.
Deposit feeder	An animal living at the bottom of a body of water that obtains food by ingesting organic material from the sediment surface, or by ingesting sediments, including organic material, as it burrows through the sediment.
"Destruction or adverse modification of critical habitat"	A direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species. Such alterations include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical. [50 CFR §402.02]
Detrivore	An animal that eats dead and decaying plants and animals.
Detritus	Dead and decaying plant and animal remains and associated microbes.
Dewatering	The result of removing water volume by reduced stream flow or lowering lake levels that exposes aquatic habitat to atmospheric conditions.
Deep-draft ports	Ports capable of handling over 15-foot draft vessels. There are five deep draft ports on the lower Columbia River: Astoria, Longview, Kalama, Vancouver and Portland.
Diatoms	Single-celled algae that have transparent cell walls composed of the hard mineral, silica.
Dike	A wall or berm built around a low-lying area to prevent tidal inundation and flooding. In the Columbia River Estuary, extensive dike systems have been erected as flood control structures, converting estuarine floodplain areas to land for agricultural and other human uses.
Diking districts	Local groups that have formed to raise money to construct, operate and maintain dikes

	to prevent flooding by the river. Agricultural and urban developed lands along the Columbia River are generally encompassed with diking districts.
Director	The Assistant Administrator for Fisheries for the National Oceanic and Atmospheric Administration; or the Fish and Wildlife Service Regional Director; or their respective authorized representative. [50 CFR §402.02]
Distinct Population Segment	"Population," or "distinct population segment," are terms with specific meaning when used for listing, delisting, and reclassification purposes to describe a discrete vertebrate stock that may be added or deleted from the list of endangered and threatened species. the use of the term "distinct population segment" will be consistent with the Services' population policy. [61 FR 4722-4725 (February 7, 1996)]
Diurnal	Activity that occurs during the day, but not at night.
Downlist	To reclassify an endangered species to a threatened species based on alleviation of any of the five listing factors provided under section 4(a)(1) of the ESA.
Drawdown	The distance that the water surface of a reservoir is lowered from a given elevation as water is released from the reservoir. Also refers to the act of lowering reservoir levels.
Dredge	Any of various machines equipped with scooping or suction devices and used to deepen harbors and waterways and in underwater mining. Also, the act of removing sediment and other material from waterways and harbors to deepen them.
Dredged Material Management Plan (DMMP)	The dredging and disposal plan that results from analyses conducted in the Dredged Material Management Study.
Dredged Material Management Study (DMMS)	An analysis of dredging and disposal alternatives that address cost, engineering, and environmental factors to operate and maintain the Columbia River 40-foot navigation channel.
Dredging forecast	A forecast of the volume needed to be dredged to maintain the navigation channel.
Early consultation	A preliminary consultation requested by a Federal agency on behalf of a prospective permit or license applicant prior to the filing of an application for a Federal permit or license. [50 CFR §402.11]
Ebb tide	Period between high tide and the succeeding low tide. the outgoing tide.
Ecology	The study of the relationships of living things to one another and to their environment.
Ecosystem	Dynamic and interrelating complex of plant and animal communities and their associated nonliving (e.g. physical and chemical) environment. Interacting organisms considered together with their environment (e.g. marsh, watershed, and lake ecosystems).
Effects of the action	The direct and indirect effects of an action on the species or critical that action. These effects are considered along with the environmental baseline and the predicted

	cumulative effects to determine the overall effects to the species for purposes of preparing a biological opinion on the proposed action. [50 CFR §402.02] the environmental baseline covers past and present impacts of all Federal actions within the action area. This includes the effects of existing Federal projects that have not yet come in for their section 7 consultation.
Embayment	Forming a bay.
El Nino / La Nina	**El Nino**: A warming of the ocean surface off the western coast of South America that occurs every 4 to 12 years when upwelling of cold, nutrient-rich water does not occur. It causes die-offs of plankton and fish and affects Pacific jet stream winds, altering storm tracks and creating unusual weather patterns in various parts of the world. **La Nina**: A cooling of the ocean surface off the western coast of South America, occurring every 4 to 12 years and affecting Pacific and other weather patterns.
Endangered species	Any species which is in danger of extinction throughout all or a significant portion of its range, and published in the Federal Register. [ESA §3(6)]
Endemic species	A species native and limited to a certain region; having comparatively restricted distribution.
Entrainment	The mechanical process by which fish are trapped. During dredging activities, fish may be entrained by the suction of hopper or pipeline dredges.
Environmental baseline	The past and present impacts of all Federal, State, or private actions and other human activities in an action area, the anticipated impacts of all proposed Federal projects in an action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions that are contemporaneous with the consultation in process. [50 CFR §402.02]
Environmental Impact	The positive or negative effect of any action upon a given area or resource.
Environmental Impact Statement (EIS)	A formal document to be filed with the Environmental Protection Agency that considers significant environmental impacts expected from implementation of a major federal action.
Environmental Protection Agency (EPA)	An independent agency of the U.S. government, created in 1970, that sets and enforces rules and standards that protect the environment and control pollution.
Eocene	Belonging to the geologic time, rock series, or sedimentary deposits of the second epoch of the Tertiary Period, characterized by warm climates and the rise of most modern mammalian families (from 40 million to 58 million years ago).
Epibenthic	Pertaining to the habitat that includes the sediment surface and the overlying one meter of water, or to the organisms that live in this habitat.
Epiphytes	Plants, such as some tropical orchids, bromeliads, or staghorn ferns, that grow on another plant upon which it depends for mechanical support but not for nutrients. Also

	called aerophytes, or air plants.
Equilibrium	A steady-state condition in which all acting influences are equally balanced, resulting in a stable or unchanging system state.
Erosion	The wearing away of the earth's surface by any natural process. the chief agent of erosion is running water; minor agents are glaciers, the wind and waves breaking against the coast.
Escapement	The number of adult fish that survive ocean conditions and fisheries to enter streams where they reproduce.
Estuarine	Relating to, or found in an estuary. Formed or deposited in an estuary.
Estuarine disposal	Deposition of materials within an estuary; here, the disposal activities occurring in the Columbia River estuary.
Estuary	The transition zone at the mouth of the lower reach of a river where freshwater and seawater mix, and is characterized by a layer of reduced salinity near the surface and a higher salinity layer below. It is the part of the course of a river where its current is met and influenced by the tides.
Estuary turbidity maximum (ETM)	An area in the water with very high concentrations of suspended matter. In many estuaries, a turbidity maximum occurs near the leading bottom tidal flow.
Eulerian-Lagrangian-CIRCulation	"Eulerian" and "Lagrangian" are two different ways of representing physical transport (of, for example, salinity) in a hydrodynamic model, and "circulation" refers to the type of hydrodynamic model itself.
Euryhaline organisms	Organisms that tolerate and are able to live in waters with wide ranges of salinity.
Eutrophic	A stage of aquatic ecosystems characterized by an accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which depletes shallow waters of oxygen, especially in summer.
Evolutionary Significant Units (ESUs)	A distinct population segment of a species that interbreeds when mature, generally genetically distinct from other groups, and representing a significant portion of the evolutionary lineage of the species.
Exotic Species	Species that have been successfully introduced into an ecosystem where they did not naturally occur.
Exploitation Rate	The rate at which a fish stock is harvested by commercial and sports fisheries.
Extinct species	A species that no longer exists.
Extirpated species	A species no longer surviving in a particular region that was once part of the species natural range.
Fall Run Chinook	Chinook of a stock that commonly return to their natal stream in the autumn. They typically have "ocean-type" young that rear in freshwater for no more than a few months before migrating to seawater.

Feasibility study	A review of factors that is conducted to help decide if a project or plan is capable of being accomplished or brought about.
Fecundity	The measurement of the production of offspring, for a fish, the number of female young produced per adult female in the population of interest.
Federal action agency	Any department or agency of the United States proposing to authorize, fund, or carry out an action under existing authorities.
Federal agency	Any department, agency, or instrumentality of the United States. [ESA §3(7)]
Federal channel	For this Biological Assessment, the congressionally authorized navigation area that is 40feet by 600feet wide on the Columbia and Lower Willamette Rivers below Vancouver, Washington and Portland, Oregon.
Feeding habitat opportunity	In this Biological Assesssment, availability to fish of the habitats that provide the feeding opportunities they need.
Fetch	An area where ocean waves are being generated by the wind.
Filter feeder	An animal that obtains food by filtering small particles of organic matter from water.
Fingerling	An early freshwater life stage of salmon that are several months old and are about finger size, usually about 40-50 mm (1.5 to2 inches) in length. Follows fry life stage.
Fish or wildlife	Any member of the animal kingdom, including without limitation any mammal, fish, bird (including any migratory, non-migratory, or endangered bird for which protection is also afforded by treaty or other international agreement), amphibian, reptile, mollusk, crustacean, arthropod or other invertebrate, and includes any part, product, egg, or offspring thereof, or the dead body or parts thereof. [ESA §3(8)]
Floodplain	The area adjacent to a river channel that is inundated during high river flows.
Flow	The volume of water, often measured in cubic feet per second (cfs), flowing in a stream past a given point per unit of time.
Flowlane disposal	For this Biological Assessment, the deposition of dredged material in deep areas of the riverbed in and adjacent to the navigation channel. See also In-water disposal.
Fluvial	Refers to a river - potential habitat in the migratory feeding history of Coastal cutthroat trout.
Food chain	Organisms that are functionally linked by their feeding habits, each feeding upon organisms that are lower in the chain and in turn being fed on by organisms higher in the chain.
Food web	The interconnection of all of the food chains in a community.
Fork length	The length of a fish measured from the head to the fork between the tail fins, rather than to the end of the tail fins.

Formal consultation	A process between the Services and a Federal agency or applicant that: (1) determines whether a proposed Federal action is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat; (2) begins with a Federal agency's written request and submittal of a complete initiation package; and (3) concludes with the issuance of a biological opinion and incidental take statement by either of the Services. If a proposed Federal action may affect a listed species or designated critical habitat, formal consultation is required (except when the Services concur, in writing, that a proposed action "is not likely to adversely affect" listed species or designated critical habitat). [50 CFR §402.02, 50 CFR §402.14]
Freshet	A major increase in stream flow due to storms or snowmelt, commonly occurring in the autumn and spring.
Fry	An early life stage of salmon that have emerged from gravel, but still within its first few months of life. Fry are generally about 30-50 mm in length. Follows alevin life stage.
Genus	A category of biological classification grouping one or more species which have fundamental characteristics in common. the first word in the scientific name of a species is the genus name.
Gillnet	A type of fishing gear that captures fish by entangling their gill covers in the meshes of the net.
Gravel Substrate	Gravel in a stream bottom or shoreline area provides a basic habitat type used by chinook for spawning and rearing.
Habitat	The location where a particular taxon of plant or animal lives and its surroundings (both living and nonliving) and includes the presence of a group of particular environmental conditions surrounding an organism including air, water, soil, mineral elements, moisture, temperature, and topography.
Habitat	The physical, biological and climate conditions that provide the environment necessary for the survival of a species, commonly a wide range of conditions for salmon.
Habitat capacity	Amount of food availability within a habitat.
Habitat complexity	The existence of a variety of habitats.
Habitat connectivity and conveyance	The ability to access a habitat.
Habitat conservation Plan	Under section 10(a)(2)(A) of the Act, a planning document that is a mandatory component of an incidental take permit application, also known as a Conservation Plan.
Habitat forming process	Those physical agents that form landscape features (hydrology, erosion, sediment, temperature, salinity, wind, waves, currents, nutrients, etc.).

Habitat opportunity	The ability of salmonids to access habitats.
Harm/Harass	See “Take”.
Hatchery Stock	Salmon that have been artificially bred and reared under hatchery conditions, generally for more than one generation. Frequently show some genetic differentiation from wild stocks, unless mixing of the two occurs on a substantial basis.
Haulout	A site where seals and sea lions congregate out of the water.
Historic range	Those geographic areas the species was known or believed to occupy in the past.
Hopper dredging	Removing river sediments using a ship equipped with pumps, dragheads (extendable, submersible arms) and hoppers (multi-thousand cubic yard containers). Hopper dredges are generally restricted to in-water disposal.
Hydraulic Control Structures	Devices constructed to manage the flow of fluids (as in water), such as dams, locks, canals
Hydrodynamics	The action and effect of fluids in motion.
Hydrographic	The scientific description and analysis of the physical conditions, boundaries, flow, and related characteristics of the earth's surface waters. the mapping of bodies of water.
Impervious Surface	Surface of the earth that has been converted from natural soil to some artificial form (such as building roofs, pavement, sidewalks, etc.) that is impervious to rainfall.
Impoundment	A body of water made by accumulating and confining or storing in a reservoir.
Inbreeding	Mating or crossing of individuals more closely related than average pairs in population.
Incidental take	“Take” of threatened or endangered fish or wildlife species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by a Federal agency or applicant. [50 CFR §402.02]
Incidental take permit	A permit that exempts a permit holder from the take prohibition of section 9 of the ESA issued by the FWS or NMFS pursuant to section 10(a)(l)(B) of the ESA.
Indirect effects	Those effects that are caused by or will result from the proposed action and are later in time, but are still reasonably certain to occur. [50 CFR §402.02]
Infauna	Aquatic animals that live in the substrate of a body of water, especially in a soft sea bottom.
Informal consultation	An optional process that includes all discussions and correspondence between the Services and a Federal agency or designated non-Federal representative, prior to formal consultation, to determine whether a proposed Federal action may affect listed species or critical habitat. This process allows the Federal agency to utilize the Services' expertise to evaluate the agency's assessment of potential effects or to

	suggest possible modifications to the proposed action which could avoid potentially adverse effects. If a proposed Federal action may affect a listed species or designated critical habitat, formal consultation is required (except when the Services concur, in writing, that a proposed action "is not likely to adversely affect" listed species or designated critical habitat). [50 CFR §402.02, 50 CFR §402.13]
Inorganic	Pertaining to matter of nonliving origin.
Interdependent actions	Actions having no independent utility apart from the proposed action. [50 CFR §402.02]
Interrelated actions	Actions that are part of a larger action and depend on the larger action for their justification. [50 CFR §402.02]
Intertidal	Characterizing the shoreline zone exposed at low tides and inundated at high tides; also, characterizing the area ecosystem and organisms between Extreme Low Tide and Extreme High Tide.
Inundated	Covered with water, especially floodwaters.
Invertebrate	An animal that does not have a backbone.
In-water disposal	For this Biological Assessment, the placement of dredged material along the riverbed in or adjacent to the navigation channel, or in designated sites below low water. Also commonly referred to as flowline disposal, this practice has been used through out the lower river system for many years. In-water disposal sites vary from year-to-year, depending on the dredging location and river depths available in the vicinity of the dredging action.
"Is likely to adversely affect"	The appropriate finding in a biological assessment (or conclusion during informal consultation) if any adverse effect to listed species may occur as a direct or indirect result of the proposed action or its interrelated or interdependent actions, and the effect is not: discountable, insignificant, or beneficial (see definition of "is not likely to adversely affect"). In the event the overall effect of the proposed action is beneficial to the listed species, but is also likely to cause some adverse effects, then the proposed action "is likely to adversely affect" the listed species. If incidental take is anticipated to occur as a result of the proposed action, an "is likely to adversely affect" determination should be made. An "is likely to adversely affect" determination requires the initiation of formal section 7 consultation.
"Is likely to jeopardize proposed species/adversely modify proposed critical habitat"	The appropriate conclusion when the action agency or the Services identify situations where the proposed action is likely to jeopardize the proposed species or adversely modify the proposed critical habitat. If this conclusion is reached, conference is required.
"Is not likely to adversely affect"	The appropriate conclusion when effects on listed species are expected to be discountable, insignificant, or completely beneficial. **Beneficial effects** are contemporaneous positive effects without any adverse effects to the species. **Insignificant effects** relate to the size of the impact and should never reach the scale where take occurs. **Discountable effects** are those extremely unlikely to occur. Based

	on best judgment, a person would not: (1) be able to meaningfully measure, detect, or evaluate insignificant effects; or (2) expect discountable effects to occur.
Iteroparous	Characterizing fish that survive their first spawning to undergo one or more subsequent spawnings (e.g., steelhead and cutthroat trout), contrast “semelparous”.
“Jeopardize the continued existence of”	To engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species. [50 CFR §402.02]
Juvenile salmon	Young salmon that have not reached sexual maturity, and generally referring to young salmon that have not yet migrated to the sea or have just entered the sea.
Larva (plural larvae)	An immature form of an animal which is unlike the adult body form and that requires fundamental morphological changes before reaching maturity.
Lentic	Characterizing water bodies that are lake types and not actively moving or flowing.
“Likely to Adversely Affect (LAA)”	Effects will result in a short-or long-term incidental ‘take’ of the listed species or designated critical habitat. See also Take.
Limnetic	Characterizing an open water area of a lake or similar body of water.
Listed species	Any species, including subspecies and distinct vertebrate populations, of fish, wildlife or plant which has been determined to be endangered or threatened under section 4 of the Act. [50 CFR §402.02]
Listing	The formal process through which the Service protects species which are then added to the Federal List of Endangered and Threatened Wildlife and Plants.
Listing priority	A number ranking system from 1 to 12 indicating the relative urgency for listing plants or animals as threatened or endangered. the criteria used to assign this number reflect the magnitude and immediacy of threat to the species, as well as the relative distinctiveness or isolation of the genetic material they possess. This latter criterion is applied by giving a higher priority number to species which are the only remaining species in their genus, and a lower priority number to subspecies and varieties. These listing priorities are described in detail in the Federal Register on September 21, 1983, as pages 43098-43105.
Littoral zone	The nearshore zone of a water body that is sufficiently shallow to permit photosythetic activity by macrophytes.
Lotic	Characterizing water bodies that are stream-like and flowing.
m	Meter
m^2	Square meter
m^3	Cubic meter

Macrodetritus	The decaying remains of multi-celled plants, such as tidal marsh and swamp plants.
Macrofauna	The group of benthic animals with lengths equal to or larger than 0.5 millimeter.
Macroinvertebrate	As used by CREDDP investigators, an epibenthic organism more than one millimeter long.
Macrophytes	Multicellular aquatic plants that attach to the bottom by roots or holdfasts, as opposed to planktonic plants.
Mainstem sediments	Materials composing a main riverbed and in contact with sediments entering from tributaries. For the Columbia River, mainstem sediments are composed of sand with typically less than two to five percent in the silt and clay size classifications.
Major construction activity	A construction project (or other undertaking having similar physical effects) which is a major Federal action significantly affecting the quality of the human environment as referred to in the National Environmental Policy Act (NEPA, 42 U.S.C. 4332(2)(C)). [50 CFR §402.02]
Marsh	A wetland area with low-lying, saturated soiles and , characterized by grassy and herbaceous vegetation and often occurring in a transition zone between water and upland.
"May Affect, Not Likely to Adversely Affect" (NLAA)	Effects to the listed species or designated critical habitat are insignificant and/or discountable. A determination of NLAA would be made for those activities that have only a beneficial effect with no short-or long-term adverse impacts.
Mean Higher High Water (MHHW)	A tidal datum defined as the average height of the higher of two daily high tides at a given place measured over an 18.6-year period.
Meiofauna	The group of benthic animals between 0.063 and 0.5 millimeters long.
mg	Milligram
Microdetritus	Decaying remains of single-celled plants and organisms, such as phytoplankton and benthic diatoms. "Imported microdetritus" are the remains of phytoplankton produced upstream that are carried downstream."Resident microdetritus" are primarily the remains of phytoplankton produced in the estuary. (See phytoplankton)
Minor change rule	When preparing Incidental Take statements, the Services must specify reasonable and prudent measures and their implementing terms and conditions to minimize the impacts of incidental take that do not alter the basic design, location, scope, duration, or timing of the action, and that involve only minor changes. [50 CFR §402.14(i)(2)]
Mitigating measures	Modifications of actions that (1) avoid impacts by not taking a certain action or parts of an action; (2) minimize impacts by limiting the degree or magnitude of the action and its implementation; (3) rectify impacts by repairing, rehabilitating, or restoring the affected environment; (4) reduce or eliminate impacts over time by preservation and maintenance operations during the life of the action; or (5) compensate for impacts by replacing or providing substitute resources or environments.

Mobile macroinvertebrates	Large epibenthic organisms that reside on the river bottom and feed on bottom sediments.
Model	A conceptualized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it; a mathematical representation of the relationships under study. the term model is applicable to a broad class of representations, ranging from a relatively simple qualitative description of a system or organization to a highly abstract set of mathematical equations.
Monitoring	For this Biological Assessment, the process of collecting and analyzing specific information to evaluate whether objectives and anticipated results of a plan are being realized or if implementation of a plan is proceeding as projected.
Mysid	A family of invertebrate animals of the crustacean class. Mysids are shrimp-like in appearance.
Natal area	The location where an animal was born, spawned or hatched.
Natal stream	The stream in which the salmon were originally spawned, incubated and reared.
National Environmental Policy Act (NEPA)	Federal legislation establishing national policy that environmental impacts will be evaluated as an integral part of any major Federal action. Requires the preparation of an EIS for all major Federal actions significantly affecting the quality of the human environment (42 U.S.C. 4321-4327).
Native stock	Salmon that are genetically derived from the wild fish that are native and have evolved in a particular watershed.
Naturally Spawning Stock	Salmon of both wild and hatchery origin that spawn unimpeded within a stream, and frequently produce some hybrid fish from the two genetic sources. Contrast wild stock.
Neap tide	Periods of minimum difference between sequential high and low tides.
Nephelometric turbidity units (NTUs)	Measurement of turbidity using a nephelometer – an apparatus that measures the size and concentration of particles in a liquid by analysis of light scattered by the liquid.
Neritic	Residing in shallow water.
No Effect (NE)	The conclusion reached in the determination of effect meaning literally no effect whatsoever to the listed species or designated critical habitat.
Nutrients	Inorganic nutrients and phosphates the enter the digestive system, both from outside sources and as a byproduct of the breakdown of the macrodetritus.
Ocean type	A life history designation for salmon that spend only a brief period (weeks to several months) rearing in freshwater and the estuary before they migrate to sea, as contrasted to “stream-type” salmon that spend at least one winter in freshwater before migrating directly to the ocean.

Oligohaline zone	The low-salinity estuarine zone of mixing fresh and salt water where juvenile salmonids go through the physiological transition necessary to adapt to a saltwater environment.
Omnivorous	Pertaining to organisms that consume both animal and plant matter.
Opportunity cost	Benefit that could result from a course of action but that is foregone when that course of action is not pursued.
Organic	Pertaining to living matter or materials of living origin.
Osmoregulation	The physiological process of maintaining an internal osmotic condition different from the surrounding water, more saline internally when in freshwater, less saline when in seawater.
Panamax	A type of deep-draft bulk carrier ship of 50,000 to 80,000 tons.
Parts per thousand (ppt)	A unit of measurement used in describing salinity. Water with a salinity of one part per thousand contains one unit of salt for every thousand units of water by weight.
Peak flow	The highest amount of stream or river flow occurring in a year, or from a single storm event.
Pelagic	Relating to, or living in, open oceans or seas rather than marine waters adjacent to land or inland waters.
Perturbation	A deviation in a normally predictable or regular cycle.
Petition (listing)	A formal request, with the support of adequate biological data, suggesting that a species, with the support of adequate biological data, be listed, reclassified, or delisted, or that critical habitat be revised for a listed species.
Photosynthesis	the process by which plants utilize radiant energy from the sun to synthesize carbohydrates from carbon dioxide and water.
Phylum	One of the principal divisions of the animal kingdom. the hierarchy of divisions used by scientists to classify the animal kingdom is phylum, class, order, family, genus, and species.
Phytoplankton	Single-celled plants suspended in the water column. Phytoplankton serve a vital role as the base of the food web on which zooplankton, benthic fauna and epibenthic organisms feed. Phytoplankton are termed "imported" if they have been produced behind the mainstream dams, or "resident" if they are produced within the lower river.
Pile dike	A structure consisting of two parallel rows of piling that are tied together and extend into the river.
Pile dike fields	Several pile dikes spaced about 1,200 to 1,500 feet apart. Within the dike field, current velocities are slowed and flow is deflected away from the river bank. the dike fields slow the current near the shore, reducing the erosion potential. Most shoreline disposal sites are provided some degree of protection from river erosion by pile dike

	fields.
Pinniped	Belonging to the Pinnipedia, a suborder of carnivorous aquatic mammals that includes the seals, walruses, and similar animals having finlike flippers as organs of locomotion.
Pipeline dredging	A method of dredging where vessels are equipped with extendable and submersible cutterheads and pumps. Material removed from a shoal by the cutterhead is pumped through a pipeline to a disposal location. Pipeline dredges are typically used for the large cutline shoals and areas with multiple sand wave shoals.
Piscivorous	Fish eating.
Plankton	The collection of small or microscopic organisms, including algae and protozoans, that float or drift in great numbers in fresh or salt water, especially at or near the surface, and serve as food for fish and other larger organisms.
Plant	Any member of the plant kingdom, including seeds, roots, and other parts thereof. [ESA §3(14)]
Polychaete	Segmented marine or estuarine worm of the annelid phylum.
Pool/riffle ratio	The ratio of surface area or length of pools to the surface area or length of riffles in a given stream reach; frequently expressed as the relative percentage of each category. Used to describe fish habitat rearing quality.
Population	"Population," or "distinct population segment," are terms with specific meaning when used for listing, delisting, and reclassification purposes to describe a discrete vertebrate stock that may be added or deleted from the list of endangered and threatened species. the term "population" will be confined to those distinct population segments officially listed, or eligible for listing, consistent with section 4(a) of the Act and the Services' population policy. [61 FR 4722-4725 (February 7, 1996)]
Post-dam periods	The time intervals after construction of the Bonneville Dam.
Predation	For this Biological Assessment, the consumption of a fish by another larger fish or other animals, also consumption of smaller organisms by fish.
Predator	Any animal that preys externally on others by hunting, killing and generally feeding on a succession of hosts (the prey).
Preliminary biological opinion	The opinion issued as a result of early consultation. [50 CFR §402.02]
Pressure gradient force	A current-creating force caused by the pressure one body of water exerts on another. The pressure is a result of differences in the density or elevation of the two bodies of water.
Primary productivity	Plant growth which, in turn, supports growth of microscopic food sources and acts as shelter.

Progradation	Seaward growth of a beach, marsh, delta, etc. by progressive deposition of sediment.
Programmatic consultation	Consultation addressing an agency's multiple actions on a program, regional or other basis.
Project baseline	Present state of the ecosystem relative to the project.
Propose	The formal process of publishing a proposed Federal regulation in the Federal Register and establishing a comment period for public input into the decision-making process. Plants and animals must be proposed for listing as threatened or endangered species, and the resulting public comments must be analyzed, before the Service can make a final decision.
Proposed critical habitat	Habitat proposed in the Federal Register to be designated as critical habitat, or habitat proposed to be added to an existing critical habitat designation, under section 4 of the Act for any listed or proposed species. [50 CFR §402.02]
Proposed species	Any species of fish, wildlife or plant that is proposed in the Federal Register to be listed under section 4 of the Act. [50 CFR §402.02]
Range	The geographic area a species is known or believed to occupy.
Range (of a species)	The area or region over which an organism occurs.
Raptor	A bird of prey, for example, eagles, hawks, owls.
Reach	See River reach/Stream reach
Refugia	Low-tide refuges (out of the high-velocity flows of the river) which provide sheltering and feeding opportunities for fish.
Rear	The process of sheltering, subsisting, living and growing, as applied to salmonids.
Rearing habitat	Areas in rivers or streams where juvenile salmon and trout find food and shelter to live and grow.
Reasonable and prudent alternatives	Recommended alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that are economically and technologically feasible, and that the Director believes would avoid the likelihood of jeopardizing the continued existence of listed species or the destruction or adverse modification of designated critical habitat. [50 CFR §402.02]
Reasonable and prudent measures	Actions the Fish and Wildlife Service or the National Marine Fisheries Service believe are necessary and appropriate to minimize the impacts (amount or extent) of incidental take. the are communicated to a federal agency in a biological opinion.
Reauthorization	A term referring to periodic action taken by Congress to reauthorize the Endangered Species Act. by reauthorizing an act, Congress extends it and may also amend it.

Reclassify	The process of changing a species' official threatened or endangered classification.
Record of decision (ROD)	A document separate from but associated with an environmental impact statement that states the management decision, identifies all alternatives including both the environmentally preferred alternatives and states whether all practicable means to avoid environmental harm from the preferred alternative have been adopted, and if not, why not.
Recovery	Improvement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Act. [50 CFR §402.02] ALSO, the process by which the decline of an endangered or threatened species is arrested or reversed, or threats to its survival neutralized so that its long-term survival in nature can be ensured.
Recovery outline	The first Service recovery document provided for a listed species. While very brief, the document serves to direct recovery efforts pending the completion of the species' recovery plan.
Recovery permit	Permits issued under Section 10(a)(1)(A) of the ESA for scientific research and other activities benefiting the recovery of Federally listed species.
Recovery plan	A document drafted by the Service or other knowledgeable individual or group, that serves as a guide for activities to be undertaken by Federal, State, or private entities in helping to recover and conserve endangered or threatened species.
Recovery priority	A number, ranging from a high of 1C to a low of 18, whereby priorities to listed species and recovery tasks are assigned. the criteria on which the recovery priority number is based are degree of threat, recovery potential, taxonomic distinctiveness, and presence of an actual or imminent conflict between the species and development activities.
Recovery unit	Management subsets of the listed species that are created to establish recovery goals or carrying out management actions. To lessen confusion in the context of section 7 and other Endangered Species Act activities, a subset of an animal or plant species that needs to be identified for recovery management purposes will be called a "recovery unit" instead of a "population."
Redd	The nest formed by a spawning female salmon as she digs in a small area of the stream bottom with her tail to form several depressions (egg pockets) in which eggs are deposited.
Regulated flow	River discharges controlled by reservoir operations.
Regulatory	Restricting according to rules or principles.
Rheotaxis	The behavioral response of a tendency to swim against a water current (positive) or with a current (negative).
Riparian area	The area immediately adjacent to streams, ponds, lakes and wetlands that directly contributes to the water quality and habitat components of the water body. This may include areas that have high water tables and soils and vegetation that exhibit

	characteristics of wetness, as well as upland areas immediately adjacent to the water body that directly contribute shade, nutrients, cover or debris, or that directly enhance water quality within the water body.
Riparian habitat conservation area	Portions of a watershed that contribute to the creation and maintenance of fish habitat.
Riparian zone	That portion of the land adjacent to a stream or body of water, usually within several hundred feet of the surface water. Normally used to refer to the zone within which plants grow rooted in water table of these streams, lakes, ponds, reservoirs, springs, marshes, seeps, bogs and wet meadows.
River discharge	The volume of water flowing through a river per unit of time.
Riverflow season	Seasons defined by CREDDP representing three characteristic river discharge periods of the Columbia River during the year. the high riverflow season is from April through June; the low riverflow season is from July through October; and the fluctuating riverflow season is from November through March.
River Mile (RM)	Mileage measurements along the main navigation channel of the Columbia River. River Mile Zero is at the river mouth.
Riverine	Relating to or resembling a river. Located on or inhabiting the banks of a river.
River reach/Stream reach	A stretch of a river or stream between two points. the U.S. Environmental Protection Agency has classified streams in the U.S. into river reaches and assigned each reach a unique number.
Safe Harbor Agreements	Voluntary agreements under which a non-Federal landowner agrees to carry out specified improvements to benefit a listed species, and the Federal government authorizes the landowner to remove the improvements at a future time and to take listed species incidental to doing so.
Saline	Pertaining to waters containing dissolved salts.
Salinity	The relative proportion of salt in a solution, such as water.
Salinity gradient	The variable rate of increase or decrease of the ratio of salinity to freshwater.
Salinity intrusion	Movement of saltwater into freshwater.
Salmonid	Fish belonging to the family salmonidae, including salmon, trout, char and allied freshwater and anadromous fish.
Sandbar	A subtidal ridge of accumulated sand.
Sandspit	A sandy point of land which projects from the shore into a body of water.
Sand wave	Waves made of sand. They cover the riverbed in the Columbia, and are typically four to eight feet high and 300 to 400 feet long. the river discharge and bedload transport affect sand wave movement. When the river discharge is less than 300,000 cfs, sand

	waves move only a few feet per day. However, when the discharge exceeds 400,000 cfs, sand wave movement can reach 20 feet per day or higher.
Scarp	A steep rock face or steep slope.
Scouring	Erosion of the riverbed.
Section 10	The section of the Endangered Species Act of 1973, as amended, that provides exceptions to section 9 prohibitions. the exceptions most relevant to section 7 consultations are takings allowed by two kinds of permits issued by the Services: (1) scientific take permits and (2) incidental take permits. the Services can issue permits to take listed species for scientific purposes, or to enhance the propagation or survival of listed species. the Services can also issue permits to take listed species incidental to otherwise legal activity. [ESA §10]
Section 10(a)(1)(A)	That portion of section 10 of the ESA that allows for permits for the taking of threatened or endangered species for scientific purposes or for purposes of enhancement of propagation or survival.
Section 10(a)(1)(B)	That portion of section 10 of the ESA that allows for permits for incidental taking of threatened or endangered species.
Section 4	The section of the ESA outlining procedures and criteria for: (1) identifying and listing threatened and endangered species; (2) identifying, designating, and revising critical habitat; (3) developing and revising recovery plans; and (4) monitoring species removed from the list of threatened or endangered species. [ESA §4]
Section 4(d) rule	A special regulation developed by the Service under authority of Section 4(d) modifying the normal protective regulations for a particular threatened species when it is determined that such a rule is necessary and advisable to provide for the conservation of that species.
Section 6	The section of the ESA that authorizes the Service to provide financial assistance to States through cooperative agreements supporting the conservation of endangered and threatened species.
Section 7	The section of the ESA outlining procedures for interagency cooperation to conserve Federally listed species and designated critical habitats. Section 7(a)(1) requires Federal agencies to use their authorities to further the conservation of listed species. Section 7(a)(2) requires Federal agencies to consult with the Services to ensure that they are not undertaking, funding, permitting, or authorizing actions likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat. Other paragraphs of this section establish the requirement to conduct conferences on proposed species; allow applicants to initiate early consultation; require FWS and NMFS to prepare biological opinions and issue incidental take statements. Section 7 also establishes procedures for seeking exemptions from the requirements of section 7(a)(2) from the Endangered Species Committee. [ESA §7]
Section 7 consultation	The various section 7 processes, including both consultation and conference if proposed species are involved. [50 CFR §402]

Section 9	The section of the Endangered Species Act of 1973, as amended, that prohibits the taking of endangered species of fish and wildlife. Additional prohibitions include: (1) import or export of endangered species or products made from endangered species; (2) interstate or foreign commerce in listed species or their products; and (3) possession of unlawfully taken endangered species. [ESA §9]
Sediment deposition or erosion	The adding (deposition) or removal (erosion) of sediments to an area by some transporting agent, such as wind or water.
Sediment yield	The quantity of soil, rock particles, organic matter, or other dissolved or suspended debris transported through a cross section of a stream in a given period. Measured in dry weight or by volume. Consists of dissolved load, suspended load and bedload.
Sediments	The organic and inorganic particulate materials, including gravel, sand, silt and clay, that cover the bottom of water bodies, including river and tributaries bottoms, estuary bottoms, and intertidal areas.
Semelparous	Species, such as Pacific salmon, that commonly die following their first spawning. Contrast "iteroparous."
Service(s)	The Fish and Wildlife Service or the National Marine Fisheries Service (or both).
Shoal	A place where a sea, river or other body of water is shallow. Also used in reference to a sandbank or sandbar in the bed of a body of water. An accumulation of sediment within the navigation channel.
Shoaling	The deposition of sediment in an area.
Shoreline disposal	Material that is dredged and pumped into shallow water and beach areas along the river. Shoreline disposal is done primarily with pipeline dredges.
Side-slope adjustment	The bedload movement is generally directed down stream, but there can be a small displacement towards deeper water caused by the side-slopes of the riverbed. This displacement is larger on steeper side-slopes.
Slack water/Slack tide	Period between low tide and high tide when the tide is neither coming in or going out.
Slough	A narrow channel cutting through an intertidal area and receiving tidal flow.
Smolt	A life stage of salmon that is undergoing or has completed the physiological transition that allows it to live in seawater. Commonly involves changes in body form to a slightly more streamlined shape and silvery body coloration.
Smoltification	Physiological transformation process young anadromous fish undergo that allows them to mover from freshwater to seawater.
Sonic tag	A battery powered transmitter that is placed in a fish that can be detected from some distance with a submerged hydrophone receiving the signal in the ultrasonic range (generally about 50-75 kHz). They allow the location of the fish to be determined.

Spawning	The releasing and fertilizing of eggs by fish.
Species	Includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature. [ESA §3(16)]
Species of Concern	An informal term that refers to those species that may be in need of concentrated conservation actions. Such conservation actions vary depending on the health of the populations and degree and types of threats. at one extreme, there may only need to be periodic monitoring of populations and threats to the species and its habitat. at the other extreme, a species may need to be listed as a Federal threatened or endangered species. Species of concern receive no legal protection and the use of the term does not necessarily mean that the species will eventually be proposed for listing as a threatened or endangered species.
Spring run chinook	Chinook that return to their natal stream in the spring. Offspring of spring chinook often display a "stream-type" life history; they rear for about a year in freshwater before migrating to the ocean.
Spring tides	Periods of maximum difference between sequential high and low tides.
Stakeholder	One who has a share or an interest, as in an enterprise.
Standing crop	The weight of a group of organisms per unit of area at a given time.
Statutory	Enacted, regulated, or authorized by statute.
Stock	Members of a species that inhabit a specific geographic area and tend to remain reproductive separate from other members of the same species.
Stranding	To drive or run ashore or aground; to leave in a difficult or helpless situation.
Stream incision	Cutting down of a stream through erosion of the stream bottom by strong currents.
Stratified, stratification	The layering of a substance. For example, water in many estuaries may have a saline bottom water layer and a fresh surface water layer.
Subduction zone	Designation of a specific area where a geologic process is occurring in which one edge of one crustal plate is forced below the edge of another.
Sub-lethal impacts	On the verge of having an extremely harmful or devastating effect.
Survival	For determination of jeopardy/adverse modification: the species' persistence as listed or as a recovery unit, beyond the conditions leading to its endangerment, with sufficient resilience to allow for the potential recovery from endangerment. Said another way, survival is the condition in which a species continues to exist into the future while retaining the potential for recovery. This condition is characterized by a species with a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, which exists in an environment providing all requirements for completion of the

	species' entire life cycle, including reproduction, sustenance, and shelter.
Suspended sediments	Soil particles that remain suspended in water due to the upward forces of turbulence and currents, and/or colloidal suspension.
Suspended solids	Organic and inorganic particles suspended in the water column.
Suspension feeders	Organisms that feed from the water column itself.
Suspension/Deposit feeders	Bottom-living organisms that feed on or at the interface between the sediment and the water column.
Swamp	Low land that is seasonally flooded; has more woody plants than a marsh and better drainage than a bog.
Take	To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct. [ESA §3(19)] Harm is further defined by FWS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering. Harass is defined by FWS as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. [50 CFR §17.3]
Taxon/Taxa	A category in a scientific classification system such as class, family or phylum.
Terminal fishery	A fishery that takes place at the location where fish enter their natal stream or near the hatchery from which they originated.
Terrestrial	Pertaining to land, as distinct from water (aquatic).
Thalweg	The line following the deepest part or middle of the bed or channel of a river.
Thermocline	A layer of sharp temperature change in a stratified body of water.
Threatened species	Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. [ESA §3(20)]
Tidal	Pertaining to tides or an area periodically flooded and exposed by the tides.
Tidal channel	A channel through which water drains and fills intertidal areas
Tidal datum	Reference elevations derived from averaging tidal measurements (for example, the average of all lower low tide measurements for a given period at a given locality is mean lower low water or MLLW).
Tidal flat	A tidal sandflat or mudflat.
Tidal marsh	An intertidal area covered with non-woody flowering plants.
Tidal mudflat	An unvegetated intertidal area composed of fine sediments, such as silt.

Tidal range	the difference between high tide and low tide.
Tidal sandflat	An unvegetated intertidal area composed of coarse sediments, such as sand.
Tidal swamp	An intertidal area covered with predominantly woody vegetation.
Tides	The periodic rise and fall of sea level produced by the gravitational forces of the moon and sun acting upon the rotating earth.
Turbidity	Reduced water clarity resulting from the presence of suspended matter; also, the amount of particulate matter suspended in water.
Unfettered river flow	River flow is not restricted.
Unregulated flow	Natural river discharge that has not been altered by reservoir operations.
Upland	High land; ground elevated above the meadows and intervals which lie on the banks of rivers, near the sea, or between hills; land which is generally dry; -- opposed to lowland, meadow, marsh, swamp, interval, and the like. Generally any area that does not qualify as a wetland because the associated hydrologic regime is not sufficiently wet to elicit development of vegetation, soils and/or hydrologic characteristics.
Upland disposal	Depositing dredged material on a site that is elevated, dry land. Upland disposal sites are designed as holding ponds, with earthen dikes to contain the dredged material and hold the sand while allowing sand and suspended material to settle. Weirs are used to regulate the return of water from the piped slurry to the river.
Velocity field	The rate or speed of flow of the river.
Vertical temperature gradient	A vertical boundary layer of substantial temperature change within a lake, estuary or test aquarium that provides fish with a choice of temperatures.
Waterborne	Transported via waterways.
Water column	(a) the water or its vertical extent; (b) the CREDDP habitat type extending from the water surface down to one meter above the sediment surface.
Water quality	the chemical, physical and biological characteristics of water.
Watershed	A geographic area contributing drainage to a specific stream, a catchment.
Water transport	the volume of water that flows past a point over a given time period.
Weir	A small dam in a river or stream.
Wetlands	Areas that are inundated by surface water or ground water with a frequency sufficient to support, and under normal circumstances do or would support, a prevalence of vegetative or aquatic life that require saturated or seasonally saturated soil conditions for growth and reproduction.
Wild Stock	Members of a species from a watershed that have continuously spawned naturally,

	and have not interbred with a hatchery population.
Wildlife	See “fish or wildlife”.
Woody debris	the fragmented remains of material consisting of, or containing wood or woody fiber, such as the woody parts of plants, logs, branches, etc. which, when deposited in streams and rivers provide shelter to aquatic creatures.
Zooplankter	An individual member of the zooplankton.
Zooplankton	The group of small (usually microscopic) passively suspended or weakly swimming animals in the water column.

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